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ABSTRACT

This document discusses the Voluntary Industry Standards for Chemical Process Industries Technical Workers Project and issues of relevance to the education and employment of chemical laboratory technicians (CLTs) and process technicians (PTs). Section 1 consists of the following background information: overview of the chemical process industries, history of voluntary industry standards development and implementation in the United States, and illustration of the skill standards in context through models of technicians' work. Examined in section 2 are the following: process used to develop the skill standards, critical issues affecting technical workers in the chemical process industries now and in the future, and the actual skill standards. Core and recommended competencies for the following eight CLT critical job functions are listed: working in the chemical process industries; maintaining a safe and clean lab; sampling and handling chemical materials; measuring physical properties; performing chemical analysis; performing instrumental analysis; planning, designing, and conducting experiments; and synthesizing compounds. Core and recommended competencies for six critical PT job functions are listed: working in the chemical process industries; maintaining safety/health and environmental standards; handling, storing and transporting chemical materials; operating, monitoring, and controlling continuous and batch processes; providing routine and preventive maintenance and service; and analyzing plant materials. Section 3 describes the study conducted to provide insight into alliance formation as a way of facilitating local-level implementation of the skill standards and the training materials resource database and tools (curriculum analysis matrix and gap analysis matrix) that were developed during the project. Appendixes contain lists of the following: steering and coordinating committee members; contract, employer, and academic institution contributors; meetings and sessions held to develop the skill standards; and standard industrial classification codes for the chemical process industries. (MN)

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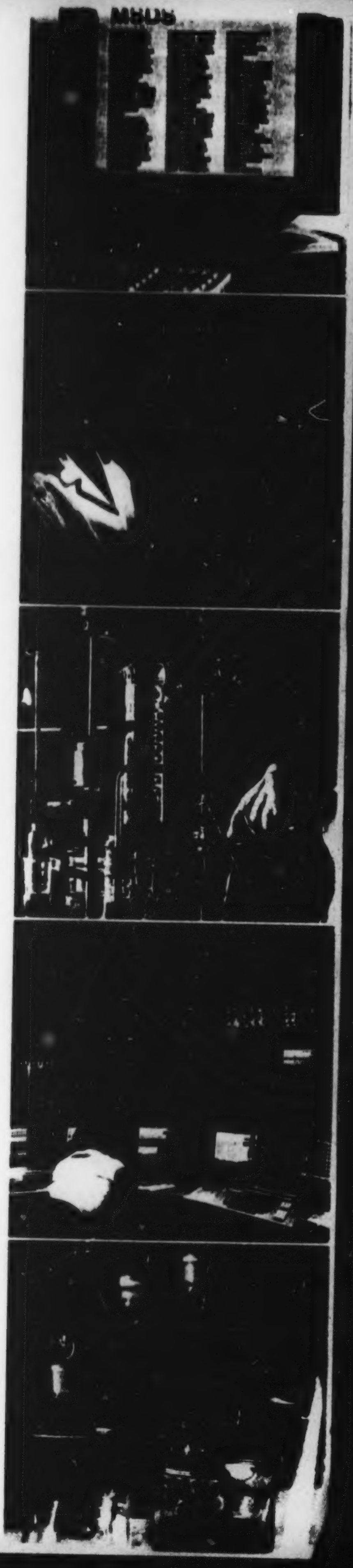
FOUNDATIONS FOR EXCELLENCE IN THE CHEMICAL PROCESS INDUSTRIES

Voluntary Industry Standards for Chemical Process Industries Technical Workers



Robert Hofstader
Kenneth Chapman

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FOUNDATIONS FOR EXCELLENCE IN THE CHEMICAL PROCESS INDUSTRIES

Voluntary Industry Standards for Chemical Process Industries Technical Workers

Collaborating Organizations:

American Association of Community Colleges
American Institute of Chemical Engineers
American Petroleum Institute
American Society for Training and Development
Chemical Manufacturers Association
International Chemical Workers Union
Partnership for Environmental Technology Education
Synthetic Organic Chemical Manufacturers Association
Technical Association of the Pulp and Paper Industry

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DISCLAIMER

This publication has incorporated the input of many individuals and organizations and provides a basis for continued analysis and debate. Thus, the specific content of this report does not reflect the position or policies of the American Chemical Society or the collaborating organizations.

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The financial support of the U.S. Department of Education totaled $2,282,392. Of this total, 48% was financed by the U.S. Department of Education and 52%, equivalent to $1,184,082, was matched by contributions from the American Chemical Society; collaborating organizations; and employers, union members, and educational institutions whose representatives served on committees and task forces and participated in data collection, writing, and validation throughout the project.

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The Voluntary Industry Standards for Chemical Process Industries Technical Workers Project has profited greatly from the cooperation and assistance of many individuals and organizations. More than 1000 individuals have given their time, experience, and resources to the project through their participation on the Steering Committee, Coordinating Committee, analysis sessions, working meetings, and skill development sessions; in writing contextual examples; and in validating draft skill standards and competencies. Their employers, including companies, government laboratories, universities, colleges, and secondary schools, have also provided support. Additionally, collaborating organizations such as the Chemical Manufacturers Association and the American Petroleum Institute have provided key connections and support throughout the project. All of these participants are listed in the appendices of this publication.

The Steering Committee was highly productive under the leadership of Committee Chair Richard Barth, Chairman of the Board, President, and CEO of Ciba-Geigy Corporation. Mr. Barth gave the project his personal attention by supporting contributions of Patrick Jackson and David Celmer, presiding at each Steering Committee meeting, and giving the keynote speech at the March 1996 American Chemical Society (ACS) Symposium during which findings of the project were presented to the general chemistry community.

The advice and counsel of U.S. Department of Education officials were extremely important to the success of this project. In particular, Patricia McNeil, Assistant Education Secretary for Vocational and Adult Education, and Kenneth Tolo, Senior Advisor to the Secretary, provided this project with the direction and support necessary for its success. Carolyn Lee, Project Officer in the Business and Education Standards Program of the Office of Vocational and Adult Education, was extremely helpful in providing assistance and counsel as the project proceeded.

The ACS bodies, including the Board of Directors, the Society Committee on Education, the Chemical Technology Program Approval Service, the Committee on Technician Activities, and the Corporation Associates Committee, gave continuous support and encouragement throughout the project. Sylvia A. Ware, Director of the ACS Education Division, supported the project from its inception. Jeffrey Allum, Staff Associate, contributed significantly to the final production of the project.

We also acknowledge the expertise of many consultants: Professor Stephen Barley of Stanford University; Judy Leff, Joyce Malyn-Smith, and Andrea Perrault of the Education Development Center, Inc.; David Munger of Strategic Education Services, Inc.; Gary Allen of Triangle Coalition for Science and Technology Education; John Byrd of the Matrix Group; Barry Hardy of Training & Development Systems, Inc.; Chris Yanckello of Business and Government Strategies, International; and Joyce Winterton of Winterton Consulting.

Robert Hofstader
Kenneth Chapman

November 1996

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PREFACE

Foundations for Excellence in the Chemical Process Industries is a report from the Voluntary Industry Standards for Chemical Process Industries (CPI) Technical Workers Project that addresses issues relevant to both the education and employment of chemical laboratory technicians and process technicians. Section I presents background information by introducing the CPI, describing skill standards development and implementation in the United States, and presenting the results of research conducted by Professor Stephen Barley and his associates at Cornell and Stanford Universities based on careful observations of technicians through the work they do and the interactions they have in the workplace (and reinforced by the work of this project). Section II describes the process used to develop the skill standards, critical issues affecting CPI technical workers now and in the future, and detailed results of the work. Section III contains contributions to the project that pertain to the implementation of skill standards. This section includes the results of work done on alliances, training materials resource database, and tools to be used by educators and industry. The appendices detail the committees, contributors, meetings, and Standard Industrial Classification Codes. A training materials resource database is provided in diskette format with this report.

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ACS TECHNICIAN ACTIVITIES

The Voluntary Industry Standards for Chemical Process Industries (CPI) Technical Workers Project was developed 30 years after the ad hoc Committee on Technician Activities (CTA) first recognized that the American Chemical Society (ACS) should engage in initiatives on behalf of chemical laboratory and process technicians. The initiatives were developed with two thrusts: raising the awareness of technicians (not then eligible for ACS membership) and preparing prospective technicians for employment by improving and extending their education.

In 1966, six members of the ACS Technician Curriculum Committee (Chairman, Carleton Roberts, The Dow Chemical Company; Henry Mealy, DuPont; William Eberhart, Georgia Institute of Technology; Kenneth Chapman, Temple University Technical Institute; Fred Deitz, Merritt College in California; and Arden Pratt, Erie County Technical Institute in New York) created guidelines for the chemistry core of two-year postsecondary chemical technology programs. In 1969, these guidelines were used as the basis for a grant to the ACS from the National Science Foundation, which resulted in the textbook series *Modern Chemical Technology*. Written by a 31-member team and edited by Robert Pecsok from the University of California, Los Angeles, and the University of Hawaii; Kenneth Chapman from ACS; and Wade Ponder from Greenville Technical Institute in South Carolina, *Modern Chemical Technology* was a significant first step toward the ACS technician initiatives.

The CTA was established in 1966 to address the interests of employed technicians. The committee's first action was to make the chemistry community more aware of technician contributions to the science and industry. In 1967, the committee initiated a technician symposium at ACS national meetings, which continues to the present time. A second effort of the committee was to train technicians, whose companies supported involvement in national-level activities, to become leaders in ACS. Technicians eventually gained eligibility to become associate members of ACS and finally full membership became available. In 1995, ACS granted full status to the ACS Division of Chemical Technicians.

Today, ACS provides direct services to technician interests in many activities. The Chemical Technology Program Approval Service gives ACS approval to postsecondary chemical technology programs. The Career Office offers job searches and publications. The Technician Resources/Education Office supports both educational and professional activities. Technicians serve on ACS committees and have been elected to Council, the ACS legislature.

With support from the U.S. Department of Education, ACS undertook the Voluntary Industry Standards for CPI Technical Workers Project in 1993. With more than $2 million of federal and in-kind funds; more than 1000 participants; and more than 130 companies, government agencies, schools, and colleges, this project has provided the first national perspective of chemical technician skills.

It is expected that this report will stimulate and provide a sound basis for the development of instructional design and alliance formation to further the nation's chemical technician workforce.

R. Barth

Ciba-Geigy Corporation
520 White Plains Road
Tarrytown, New York 10591

November 30, 1996

To: Educators and Employers of Chemical Process Industries (CPI) Technical Workers

For the past three years I have had the privilege of chairing the Steering Committee for the Voluntary Industry Standards for CPI Technical Workers Project. The project focused on identifying the knowledge and skills expected of entry-level chemical laboratory technicians and process technicians. More than 110 employers (companies, university research units, and government agencies); industry organizations such as the Chemical Manufacturers Association, the American Petroleum Institute, and the Technical Association of the Pulp and Paper Industry; professional societies such as the American Chemical Society; academic and educational institutions; and union workers, particularly through the International Chemical Workers Union, have enthusiastically supported the effort by contributing many hours to develop the skill standards. Technical workers participated in work analysis sessions during which tasks and performance skill standards were identified. Human resource specialists, technical leaders, experienced educators, and corporate managers focused on the future roles of technical workers and the skills required to meet the needs of changing work environments. Workers at all levels reviewed and validated the output. The result is a comprehensive set of performance-based knowledge and skills that the CPI believes should be brought to the workplace by technicians.

The success of chemical laboratory technicians and process technicians, however, is not in the drafting of the skill standards, but rather in how these standards will be implemented to develop workers with the necessary skills to maintain America's high standards of performance in the CPI. To meet that end, skill development modules have been developed for use by both public and private educators. As we move to the future, we must seek ways by which industries, educational institutions, labor, and communities can work together to implement the skill standards.

On behalf of the CPI, I would like to acknowledge the support of the U.S. Department of Education; the companies, educators, and participants who dedicated their time and resources to this initiative; and the work carried out by the American Chemical Society as we enter a new phase of chemical education in the United States.

R. Barth

EXECUTIVE SUMMARY

As part of the effort by the U.S. Departments of Education and Labor to develop voluntary industry standards, the U.S. Department of Education awarded a grant to the American Chemical Society to develop the Voluntary Industry Standards for Chemical Process Industries (CPI) Technical Workers. This grant was matched by contributions from industry, education, collaborating organizations and, in particular, the American Chemical Society. The results of the work carried out on behalf of this grant are the subject of *Foundations for Excellence in the Chemical Process Industries.*

The CPI was defined to include companies that develop and add value to products through the application of chemistry and/or that apply chemical principles and techniques to conduct work. The industrial sectors included in this study are in Standard Industrial Classification (SIC) codes 28, 29, and 30 as well as 8731, 8733, and 8734. A complete list of the SIC codes is given in Appendix G of the report. The workers for whom skill standards were developed are chemical laboratory technicians (CLTs) and process technicians (PTs). PTs are often referred to in the industry as process operators.

Both occupations chosen for study were considered to be highly important to the industry now and in the future. The diversity of the industry resulted in the need for technical workers to apply knowledge and skills to a variety of different plant and laboratory operations. As background for the project, a complete review of the research conducted by Dr. Stephen Barley, Stanford University, was conducted. Dr. Barley and his colleagues studied technicians in the workplace and have developed extensive insights into the contributions made by technicians and how the occupation fits into the overall organizational structure. In collaboration with Dr. Barley, we conclude that the CLT and the PT fit into the category of "buffer" technicians because they collaborate with the scientists and engineers with whom they work. Likewise, we conclude that the most suitable organizational structure is that depicted by an "interlocking" model because technicians have certain skills and knowledge to bring to the workplace that differ from those of scientists and engineers. There is, however, a zone in which the skills and knowledge overlap and the translation of roles takes place. A clear definition of skill standards permits this model to be implemented.

The voluntary industry standards include a comprehensive set of statements that describe a broad consensus about the knowledge and skills required for CLTs and PTs to contribute effectively in the workplace. The skill standards, as they are presented in the report, are intended to be "building blocks" to be used by industry and education in the development of curricula, training programs, worker competency assessment tools, instructional materials, and other related activities.

The three-year project was conducted in two phases. The first phase focused on determining the actual work conducted by CLTs and PTs now and the skills needed for the future. The second phase focused on what technicians need to learn and what competencies they need to perform in the workplace.

PHASE I

To determine the work conducted by technicians and the expectations for the future, input was derived from technicians working in the industry, technical and human resource managers, government and university laboratories, unions that represent technicians, and industry and professional societies. The information obtained represents various geographical areas and different components of the industry.

The data used to determine the actual work carried out by CLTs and PTs now and into the future were collected in two discrete segments: analysis sessions and working meetings. A summary of each, with the outcomes, follows.

Analysis Sessions

Data were collected from technicians at analysis sessions in Baton Rouge, Louisiana; Cincinnati, Ohio; Berkeley, California; Chicago, Illinois; Newark, New Jersey; and Research Triangle Park, North Carolina. The locations were chosen to represent geographic and industry differences across the nation. Each session involved 10–18 CLTs and PTs and was conducted using a modified DACUM (Design A CUrriculuM) process. This process gave each participant an opportunity to contribute, in detail, to the actual work done.

The data provided were analyzed and sorted into Critical Job Functions, tasks, and workplace standards required to perform the tasks. The workplace standards were further separated into two groups: employability workplace standards, which were pertinent to all Critical Job Functions, and technical workplace standards, which were specific to Critical Job Functions. The employability workplace standards were further categorized as:

- mathematics and statistics
- computer literacy
- communications

Continued

The Critical Job Functions performed by CLTs are:

- Working in the Chemical Process Industries
- Maintaining a Safe and Clean Laboratory Adhering to Safety/Health and Environmental Regulations
- Sampling and Handling Chemical Materials
- Measuring Physical Properties
- Performing Chemical Analysis
- Performing Instrumental Analysis
- Planning, Designing, and Conducting Experiments
- Synthesizing Compounds

The Critical Job Functions performed by PTs are:

- Working in the Chemical Process Industries
- Maintaining Safety/Health and Environmental Standards in the Plant
- Handling, Storing, and Transporting Chemical Materials
- Operating, Monitoring, and Controlling Continuous and Batch Processes
- Providing Routine and Preventive Maintenance and Service to Processes, Equipment, and Instrumentation
- Analyzing Plant Materials

Each Critical Job Function is associated with tasks and technical workplace standards, which are presented in detail in the report.

Working Meetings

Working meetings of industrial human resource and technical managers and other leaders led to identification and clarification of major issues that will affect the qualifications of CPI technical workers in the future. These data collection meetings were held in Houston, Texas; Seattle, Washington; and Philadelphia, Pennsylvania. These locations were chosen to provide geographical and industrial diversity. Each meeting consisted of representatives, primarily from industry, who focused on the following four major issues:

- Issue 1: The interface between the chemist/chemical engineer and the CLT/PT
- Issue 2: Industry trends
- Issue 3: Technology trends
- Issue 4: Safety/health and environmental regulations

The impact of these issues on CLTs and PTs is presented in the report, and the data have been incorporated into the skill standards.

PHASE II

To determine the skills and knowledge required by technicians to perform the work competencies, skill development sessions were conducted.

Skill Development Sessions

Skill development sessions were conducted for each of the Critical Job Functions derived from the analysis sessions and working meetings. These facilitated focus group sessions were primarily made up of two-year college faculty and industrial training professionals and focused on answering the question, "What competencies do technicians need if they are to perform according to the technical and employability workplace standards?" In addition to the competencies, each group was asked to provide contextual examples of how the particular competencies were used in the workplace. Analysis of the data obtained from these sessions resulted in the skill development modules to support each of the Critical Job Functions, with a cross-reference to the employability standards. The skill development modules were designed to contain the competencies required of technicians to master the skills. Competencies have been designated as either core or recommended. In all, there are 14 Critical Job Functions with 113 skill development modules containing 1025 technical competencies.

To support the implementation of the skill standards, the project developed several supportive tools, including:

- criteria for the development of government, education, industry, labor, and community alliances
- tools to determine the gap between the standards considered to be important by local industry and the standards being taught in educational institutions
- a database that contains more than 1200 references to training materials available from 30 commercial and noncommercial sources sorted according to the Critical Job Functions and skill development modules

The report contains the details of the work done and presents the results. It is designed to be a reference for those involved with education and workforce development and should be used to create a technician workforce that will provide the U.S. CPI with the highest performance in the world economy.

SECTION I:
BACKGROUND INFORMATION

OVERVIEW OF THE CHEMICAL PROCESS INDUSTRIES

VOLUNTARY INDUSTRY STANDARDS DEVELOPMENT AND IMPLEMENTATION IN THE UNITED STATES

SKILL STANDARDS IN CONTEXT: MODELS OF TECHNICIANS' WORK

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The term "chemical process industries" (CPI) was coined years ago to include many industry categories that use chemistry in value-added manufacturing processes. The CPI include the companies listed in the Department of Labor's Standard Industrial Classification (SIC) code categories 28, 29, and 30 as well as 8731, 8733, and 8734. A list of the industry groups included within the categories appears in Appendix G. The chemical industry, the largest component of the CPI, is the fourth largest U.S. manufacturing industry and provides about 6% of all manufacturing jobs at wages about one-third above the manufacturing wage average. In 1991, the CPI had sales of $290 billion and provided a positive U.S. trade balance of $18.8 billion.

CPI technical workers are divided into two occupational groups for this report: chemical laboratory technician (CLT) and process technician (PT). The broad definition of the CPI used above encompasses about 240,000 CLTs and slightly fewer than 500,000 PTs. CLTs and PTs are employed by companies, as defined for this project within 91 SIC codes, as well as cities, states, federal government laboratories, and non-CPI employers as diverse as electronics and automobile manufacturing.

Education and workforce reforms have targeted many different occupations and people over the past 40 years. For example, following the launch of Sputnik in 1957, education reformers concentrated on developing scientists, engineers, and other high-level technical personnel, and in the 1970s, minorities and "at risk" youth were the focus of education. The competency-based education strategy of the 1970s was one approach of many used to enhance skill and knowledge development of workers in the United States.

In the early 1980s, education and workforce initiatives began to focus on those individuals who were employed in manufacturing and service sectors of the economy. This trend in education and workforce initiatives was sparked, in part, by the National Commission on Excellence in Education's publication of *A Nation at Risk* (1983). The report examined the economic and employment problems of the United States and concluded that the lack of appropriate education was an important contributor to a perception of declining competitiveness. The report argued that this perception increased inequality in American society and fostered a static standard of living.

In an attempt to develop more responsive educational programs, postsecondary institutions began to use a data collection process called DACUM (Design A CUrriculuM) to obtain information from workers to design curricula. However, no mechanisms were developed to facilitate linking the information with educational programs or to foster articulation between school and the workplace to stimulate development of instructional materials.

To address these issues, the U.S. Departments of Education and Labor were commissioned by Congress to undertake a major effort to develop voluntary industry standards. In 1993, 22 pilot projects were funded to develop skill standards. The American Chemical Society received a grant from the U.S. Department of Education to develop skill standards for chemical process industries. The results of the work are the subject of this report.

In 1995, the National Skill Standards Board was created to guide development of a skill standards system. The system being considered would be a crucial part of a broader reform strategy to facilitate innovative approaches to aligning human resource education with the demands of the economy. More recently, several states have undertaken major efforts to adopt skill standards.

SKILL STANDARDS IN CONTEXT: MODELS OF TECHNICIANS' WORK

Contributors: Stephen Barley, Robert Hofstader, Kenneth Chapman

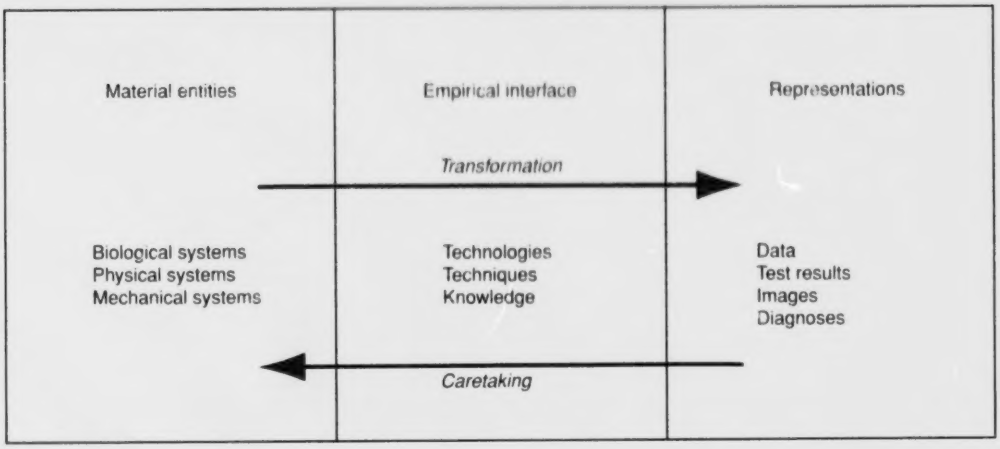
BACKGROUND

Despite technicians becoming the fastest growing occupational category in the United States and many blue- and white-collar jobs being transformed by new technologies into jobs that resemble technicians' work (Barley in press; Zuboff 1989), until recently there was almost no research on technicians. In 1990, in response to this dearth of information, researchers associated with the National Center for the Educational Quality of the Workforce began a five-year ethnographic study of the role of technicians in organizations. The researchers investigated an array of occupations, including technicians in molecular biology laboratories (Barley and Bechky 1994), emergency medical technicians (Nelsen in press), technicians in pathology labs (Scarselletta in press), computer technicians (Zabusky and Barley in press; Zabusky in press), engineering technicians (Darr 1996), radiological technicians (Barley 1990), automotive technicians (Nelsen in preparation), and technicians in semiconductor equipment manufacturing (Bechky in preparation). Each study involved eight to twelve months of participant observation during which researchers worked along side practicing technicians from two to four days per week. The group's objective was to develop a grounded theory of what technicians do, what technicians know, and how technicians experience their work. Out of these studies a general model of technicians' work has emerged.

Common Core

The model revolves around a common core that seems to characterize all technicians' work. As Figure 1 indicates, technicians usually work at an empirical interface that separates the material world from a world of symbols and representations.

Figure 1. Nonrelational aspects of technicians' work: The empirical interface.



Depending on the specifics of the technician's work, the relevant material world might be a biological (the human body, a cell culture), a mechanical (a computer network, a manufacturing technology), or a physical (a chemical process) system.

Similarly, depending on context, relevant representations might consist of data, test results, images, diagnoses, or even theories. As Figure 1 illustrates, the technician's task at an empirical interface revolves around two complementary processes: transformation and caretaking.

Technicians use technologies, techniques, and other knowledge to transform aspects of the material world into symbolic representations. For instance, technicians in medical settings produce images, counts, assays, and other data useful for medical diagnosis (Barley 1990; Scarselletta 1992; Nelsen and Barley 1996). Technicians in factories create and monitor flows of information on production systems (Zuboff 1989). Science technicians reduce physical phenomena to data or "inscriptions" from which scientists construct arguments, papers, and grants (Latour and Woolgar 1979; Barley and Bechky 1994).

Technicians, however, do more than generate symbols and information. Most are also responsible for overseeing physical entities (e.g., machines, organisms), ensuring that they remain intact and in good working order. In fact, caretaking often requires technicians to use the representations they create. For example, technicians in biology labs use the data they generate to husband organisms and monitor technologies (Barley and Bechky 1994), and microcomputer technicians use the results of tests and probes to alter the functioning of computer systems.

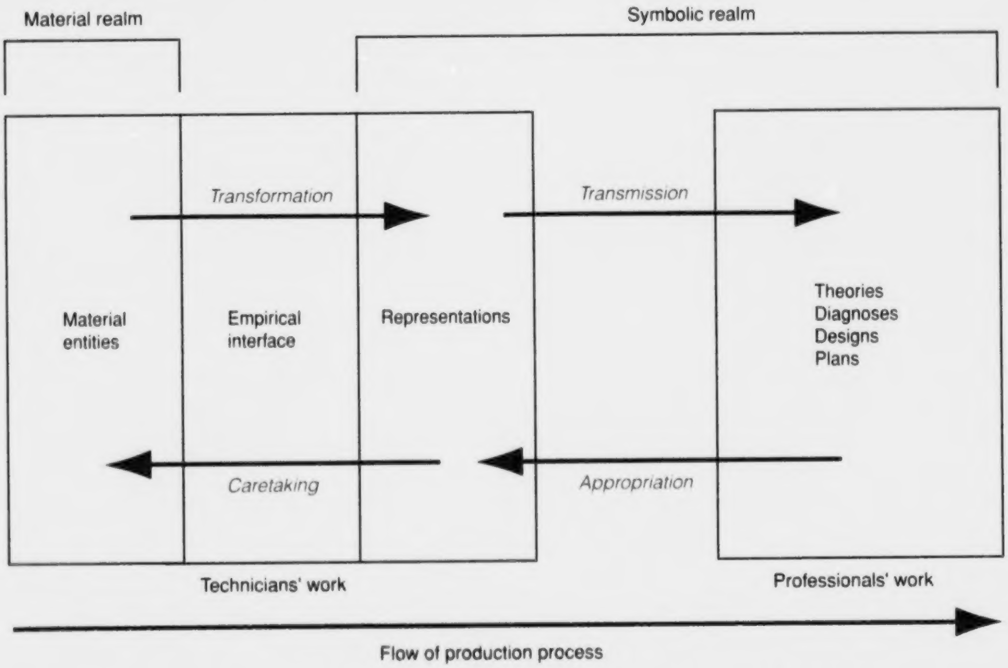
Buffers

Barley (in press) has argued that technicians' work varies according to how this common core is situated in a larger system of production. The first type is technicians who work along side members of professions. The representations that these technicians create become input for the professional's work. Prototypes of this type include technicians in scientific laboratories, medical technicians, and engineering technicians. Barley (in press) labels these technicians "buffers." In contrast, the second type of technician primarily maintains systems that enable other people to do their jobs. Rather than create input for the work of others, these individuals build and maintain infrastructures that allow work to take place. Programmers, computer technicians, and other kinds of technicians who repair equipment are prototypical of this type of technician, whom Barley calls "brokers." Of the two types of technicians, the buffer is most relevant for understanding the work of technicians in the chemical process industries (CPI).

Buffers provide scientists, engineers, and physicians with information to develop theories, designs, and diagnoses. But buffers do more than simply produce data; they also shield the professionals who use the data from empirical phenomena. For instance, because science technicians operate lab equipment and conduct experiments, it is usually they, rather than scientists, who preside over encounters with the physical world. Consequently, scientists do not have to concern themselves with the practical uncertainties of empiricism. Similarly, by stabilizing patients at the scene of an accident, emergency medical technicians relieve physicians and nurses of the need to do triage. Radiological technologists and medical technicians likewise distance radiologists and pathologists from patients and their bodily tissues and fluids, respectively.

Figure 2 summarizes the buffer's position in a system of production. The flow of activity moves from left to right, with the technician first reducing physical phenomena to representations and then conveying those representations to a professional, who operates on the representations to synthesize a more complex, symbolic product. The figure highlights three critical points about the buffer's role. First, because buffers link the material world to a symbolic world, they are responsible for ensuring referential meaning. Their practices and skills determine the quality of the correspondence between representations and what the representations presumably signify. Second, buffers and professionals share a social world, whether it is the world of a medical specialty, a scientific discipline, or another substantive domain. Thus, they are members of the same speech community. For this reason, buffers can transmit the representations they create directly to a professional without translation. For example, emergency room physicians often use an emergency medical technician's initial assessments to begin treatment. Radiologists often dictate diagnoses based entirely on a sonographer's images and interpretations. Scientists frequently incorporate data assembled by technicians into arguments, papers, grants, and theories without further analysis. The more faith professionals have in the referential quality of the technician's representations, the more likely they are to accept the technician's data without question.

Figure 2. Buffer technicians.


Material realm
Symbolic realm
Transformation
Transmission
Material entities
Empirical interface
Representations
Theories
Diagnoses
Designs
Plans
Caretaking
Appropriation
Technicians' work
Professionals' work
Flow of production process

Membership in a common speech community leads to a third characteristic of the buffer's work. Buffers routinely appropriate the professional's theories, plans, diagnoses, or designs to guide their own work at an empirical interface. To troubleshoot prototypes, engineering technicians have to read and understand the engineer's schematics and calculations. By drawing on elements of scientific theory, technicians in biology labs puzzle through the enigmas that inevitably arise during experimental procedures. Sonographers must understand pathological processes to capture diagnostically useful information.

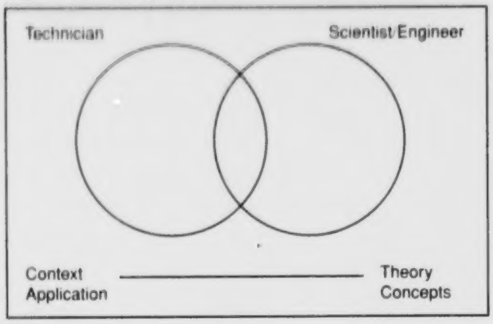
In short, buffers ensure the smooth production of representations and the integrity of a physical system by managing problems at the empirical interface where they work. This requires that they comprehend the principles of the technologies and techniques that they use as well as more abstract and systematic bodies of knowledge about their piece of the material world. In this respect, technicians resemble the professionals with whom they work. Like scientists, science technicians require knowledge of mathematics as well as the science on which their practice is based (Barley and Bechky 1994). Emergency medical technicians, sonographers, and medical technologists similarly require knowledge of biological systems, pharmacology, and disease processes to render diagnostically useful information. Without such formal knowledge, technicians cannot optimally perform their caretaking functions.

Contextual Knowledge

Buffers manipulate physical entities to create representations and achieve practical ends, they must also possess extensive contextual knowledge of their materials, technologies, and techniques. Contextual knowledge is largely particularistic, acquired though practice, and difficult to verbalize or codify. Contextual knowledge consists, in part, of a technician's ability to read subtle visual, aural, and tactile cues where others see no information. Contextual knowledge also encompasses sensory-motor skills, knowledge of heuristics and rules of thumb geared to the materials with which the technicians work, familiarity with a local history of problem solving, and access to technical knowledge held primarily by other technicians (Barley in press). In this sense, then, the technician's work resembles a craft. Craftpersons have long been valued for their ability to render skilled performances based on an intuitive feel for materials and techniques (Harper 1987; Becker 1978). Studies show that technicians pride themselves on and are prized by others for precisely the same sort of skill. For instance, Cambrosio and Keating (1988) report that technicians in monoclonal antibody laboratories are often unable to fully articulate their techniques for producing viable hybridomas. Consequently, labs frequently cannot duplicate each other's work even when procedures are meticulously documented. Instead, the transfer of technical knowledge usually requires one laboratory to dispatch technicians to another, and even then, the recipient may be unable to cultivate the cell line.

The foregoing discussion indicates that buffer technicians and the professionals with whom they work share a pool of knowledge. Technicians are familiar with the scientific and technical principles that inform the professional's training and expertise. Conversely, scientists, engineers, pathologists, and radiologists can, if necessary, stand in for technicians. Yet, the professional's knowledge of materials, technologies, and techniques is skewed toward a principled understanding, whereas the technician's is weighted toward the contextual. Both types of knowledge are equally necessary for accomplishing tasks. Consequently, buffer technicians and professionals with whom they work are best understood as members of distinct occupations who contribute unique but complementary skills and knowledge to the work process. The underlying logic of the distribution of knowledge in settings where buffers work is illustrated in Figure 3. The critical importance of the technician's skills is stated in the following comment by an accomplished molecular biologist and lab director interviewed by Barley and Bechky (1994):

Figure 3. Interlocking occupational division of labor.



> I did tissue culture for six years and was pretty good at it. Fifteen years ago, I knew the state of the art. But now, I don't know what they are using to wipe down the incubator. I have no hands-on knowledge of the cells. [Our research support specialist] can tell immediately if the cells are happy, from all the hours she spends looking at them. This is where the art comes in. It isn't mystery or mysticism, just the things that you don't consciously know—they are at the edge of your consciousness. Subtle things. A tech will say, "This doesn't look quite right." No one ever tells you these things; they aren't written down in books... . I have seen lab directors ruin their lab by giving orders to an RSS [research support specialist] or a tech who should be an RSS.

For all practical purposes, then, the research conducted by Barley and his colleagues suggests that technicians are members of distinct occupations.

TECHNICIANS IN THE CHEMICAL PROCESS INDUSTRIES

We usually say that people belong to a distinct occupation when they bring to the workplace important skills and knowledge that they alone possess. When people do not possess unique knowledge and skills, we typically say they have a job, not an occupation. Until recently, chemical laboratory technicians (CLTs) and process technicians (PTs) were not understood as members of bona fide occupations, in part because detailed information on the work of technicians in the CPI either did not exist or was poorly documented. The work defining skill standards reported in this document has largely alleviated that problem.

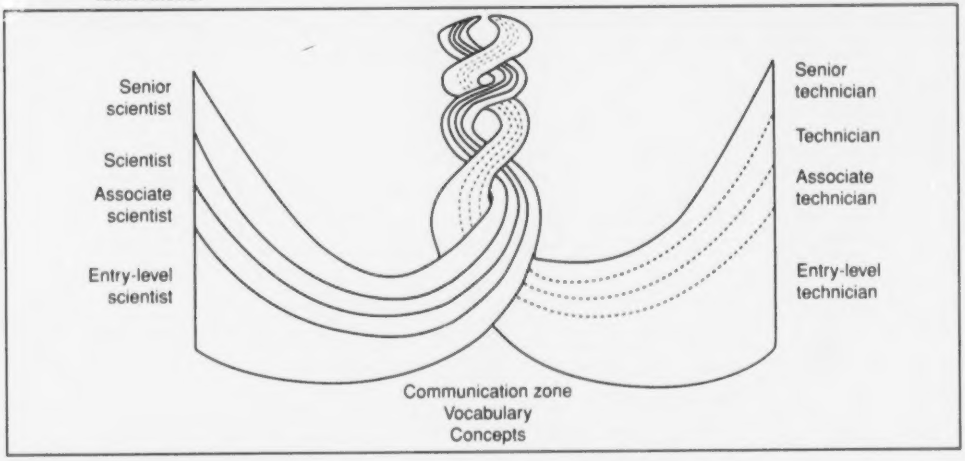
In June 1993, with funding from the U.S. Department of Education, researchers associated with the American Chemical Society embarked on a three-year study. The project has provided insight into the work of CLTs and PTs in two ways. First, the work of these technicians was specified in substantive terms through a rigorous process that involved more than 1000 technicians and that led to performance-based skill standards composed of 1025 statements of competency grouped into 14 Critical Job Functions. (A complete compilation of the results appears in Section II of this report.) Second, the changing social role of the technician within CPI firms was identified in interviews and focus groups with more than 150 technical and human resource managers representing more than 80 companies. These insiders acknowledged substantial changes in the technician's role and linked those changes to: (1) shifting relationships between technicians and scientists; (2) industry trends; (3) technology trends; and (4) the impact of safety, health, and environmental regulations.

Although it is not yet common for firms in the CPI to accord a distinct occupational status to CLTs and PTs, data collected for the Voluntary Industry Standards Project suggest that there is reason to believe the situation is changing. An increasing number of firms in the CPI appear to have become dissatisfied with their ability to recruit technicians and with the skills of those technicians they do recruit. Many are expanding their expectations of CLTs and PTs and have begun to ask technicians to take on more responsibility. The findings presented in this report on pp. 34 and 35 indicate several reasons why firms' expectations of technicians are changing. First, the use of team approaches in the laboratory and plant requires more complementary and synergistic roles between scientists (or engineers) and technicians and empower the latter to contribute beyond their required tasks. Second, as firms in the CPI continue to rightsize, uncertainty about the stability of the workforce will lead firms to seek technicians who have multiple skills and who are adaptable and flexible. Third, an increasing number of technicians will be hired as contract workers and will therefore require portable skills, the key hallmark of an occupation. Finally, the nature and pace of technological change is of importance. The emergence of microelectronic control and monitoring systems, the increasing use of biological technologies in the chemical industry, growing concerns about safety and environmental hazards, expectations regarding quality, and new techniques of simulation seem to demand broader and deeper analytic skills.

The resulting compendium of skills is testimony to the fact that practitioners at least unofficially recognize that technicians' skills differ considerably from those expected of a scientist or engineer and that both sets of skills are symbiotically related. Although the results indicate that technicians need to know techniques (e.g., solving simultaneous equations, conducting statistical analyses) and theories (e.g., those of thermodynamics) commonly taught to scientists, most of the skills enumerated by the Voluntary Industry Standards Project focus on laboratory practice, situated forms of analysis, and decision making. Furthermore, the skill standards place great emphasis on written and oral communication as well as on interpersonal skills required for group problem solving.

Thus, the content of the Voluntary Industry Standards Project report recapitulates the image of a technician that emerges from the research conducted by Barley and his colleagues. In particular, the skill standards show that a technician's unique expertise lies in his or her contextual knowledge of materials and techniques. The skill standards' heavy emphasis on communication and teamwork explicitly demonstrates that technicians collaborate in a multidisciplinary milieu and that technicians bring critical knowledge and skills to the team. In fact, because CLTs generate data and other forms of information necessary for the work of chemists and because PTs take care of production systems and produce data for engineers and managers, it would seem that both kinds of technicians would be considered buffers. Although Barley and his colleagues did not study the CPI directly, they build their model of a buffer on observations of science and engineering technicians in similar contexts. To the degree that science and engineering practices are similar, despite differences in context, the general model of a buffer technician should apply equally well to the work of CLTs and PTs. Embracing the skill standards should therefore facilitate a more explicit recognition that technicians are members of identifiable, distinct occupations. The implicit message of the skill standards project is that the typical workplace in the chemical industry can be described in terms of a structure that is composed of two realms of technical expertise: (1) the symbolic realm of the scientist or engineer and (2) the physical realm of the technician. One possible description of this bifurcated structure is suggested by Figure 4, in which the two realms are linked by a common set of knowledge and skills that permits communication and, ultimately, delivers results. Such a model provides a logic for a team-driven organization and supports the notion that chemical technicians belong to distinct and identifiable occupations.

Figure 4. A bifurcated structure for the science workplace, showing the working interaction of scientists and technicians.

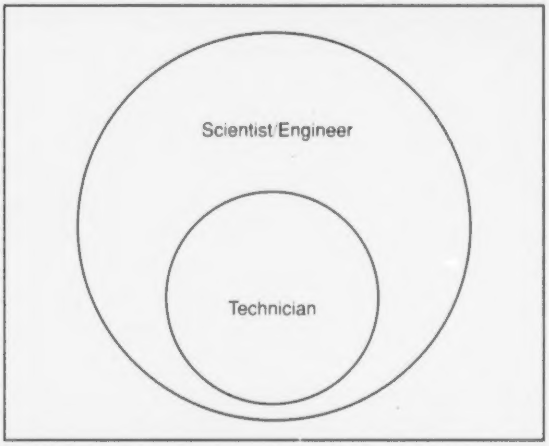


OCCUPATIONAL MODELS

It would be a mistake, however, to assume that adoption of the skill standards will automatically or by itself lead to widespread recognition of CLTs and PTs as members of a distinct occupation. The difficulty arises because we often organize work based on our images of how we think knowledge is distributed rather than according to how skills and knowledge are actually distributed. Images of a firm's division of labor are usually encoded in organizational charts, job descriptions and, less officially, institutionalized patterns of communication and behavior. Although routines and regulations can make a division of labor appear to be an objective phenomenon, it is important to realize that divisions of labor are primarily models that we use to make sense of and to structure our actions and interactions. For this reason, it is entirely possible for an organization to operate with a division of labor that inaccurately represents its actual distribution of knowledge and skills. In such instances, organizations are unlikely to make optimal use of their employees because the nature of their skills may not be recognized, respected, and rewarded.

Historically, neither firms nor schools have acknowledged CLTs and PTs as members of bona fide occupations, with unique and valuable skills. Rather than portray technicians and scientists (or engineers) as members of an interlocking, occupational division of labor (as in Figure 3), the educational and human resource literature routinely speaks of CLTs and PTs as "junior professionals" whose work requires a less rigorous, and perhaps more applied, version of the formal knowledge required of chemists and engineers. The logic of the distribution of knowledge implied by the notion of a junior professional is depicted in Figure 5. Here the technician's knowledge and skills are conceptualized as a proper subset of what professionals know. At best, technicians are treated as semiprofessionals.

Figure 5. Semiprofessional/professional division of labor.



For this reason, educators often design CLT training programs explicitly to help students move smoothly into B.S. chemistry programs, and evidence suggests that as a result many do (Hofstader and Chapman 1994). There is little in the curricula of such programs to suggest that CLTs might require skills and knowledge that complement those of a chemist and that such skills are necessary for solving problems that are distinct from the problems that chemists solve. The issue is somewhat different for PTs who generally are hired for maintenance or related jobs and who usually develop their skills and knowledge on the job. Until recently, only a few programs existed for entry-level PTs.

The tendency to view chemical technicians as junior professionals probably arises from three sources. First, until the development of skill standards, little interest was shown in examining what technicians actually do and how their skills and knowledge fit into the larger system of which they are a part. When assessments were made, they usually judged what technicians knew against what chemists and engineers knew, rather than inventory the substantive knowledge that technicians actually possess. Second, because technicians' work has a significant sensory-motor component and because it involves tasks that professionals consider routine or distasteful, technicians' work elicits cultural stereotypes about the relative status of mental and manual labor (Whalley and Barley in press). Third, technicians have historically been drawn from the ranks of operators and maintenance workers (especially in the case of PTs) or have been individuals whose circumstances prevented them from entering or completing the advanced degrees required of a scientist or engineer.

Because it is possible to demand new skills while maintaining old images of the way the knowledge is distributed, attempts to institute skill standards may be less effective than anticipated. First, trained technicians may find themselves in situations where they are unable to make full use of and feel valued for their knowledge because the organization does not operate in a way that takes full advantage of their expertise.

Second, as a result, it may be difficult to attract or retain new recruits who perceive that they are not being rewarded or respected for what they know. The research literature on technicians explicitly acknowledges these problems.

A consistent theme in the small but growing literature on technicians is the disjuncture between the importance of what technicians do and know and their relative status in the organizations where they work. Barley and Bechky (1994) report that even though many scientists informally acknowledge that technicians are critical to scientific work, their criticality rarely translates into formal recognition. Zabusky and Barley (in press) report that similar problems characterize the work of computer technicians, medical technicians, emergency medical technicians, and engineering technicians. In fact, Koch (1977) and Evan (1964) have argued that "status inconsistency" may be the defining cultural characteristic of technicians' work.

Recognition incommensurate with skill and contribution undoubtedly helps explain the problems that researchers claim are endemic to technicians' work. Studies consistently show that technicians demonstrate considerable knowledge and responsibility but receive low pay and little respect even when they hold postsecondary degrees. Zabusky and Barley (in press) report that the average starting salary a technician with an associate's degree in medical technology or electrical engineering in upstate New York, where their research was conducted, averaged $22,000. Low salaries and high skill demands set conditions that make it difficult to recruit newcomers to technicians' work.

Barley and Bechky (1994) report that incommensurate respect seems to explain why science technicians often move from lab to lab and employer to employer. At first glance, this job hopping appears to be a quest for greater remuneration and, indeed, technicians do report changing employers to increase their salaries. But interviews reveal that pay is rarely the only or even the primary motive for movement. Most science technicians report that they move from lab to lab in search of a scientist or an organization that is willing to grant them the autonomy, recognition, and respect they believe their skills and sense of responsibility warrant. Once science technicians find such a lab, they tend to remain for a long time.

There are at least three cultural reasons why technicians receive rewards that are incommensurate with their substantive contributions. First, and perhaps most important, technicians' work blurs the long-standing distinction between mental and manual work and therefore systematically violates the percepts by which Westerners allocate status to work (Whalley and Barley in press). To restore cognitive order, employers and co-workers often emphasize the manual rather than the mental aspects of technicians' work, which enables them to treat technicians more like blue-collar workers than professionals. Second, the tendency to resolve technicians' cultural ambiguity by devaluing their work is reinforced by the higher value modern Western cultures place on formal knowledge compared with that of contextual knowledge. As we have noted, the greater value afforded formal knowledge is reflected in most degree-granting technician education programs, which emphasize a theoretical rather than an applied understanding of science, even though technicians repeatedly report that on the job they use very little of what they learn in school. Finally, the disjuncture between the importance of what technicians do and know and the recognition they receive is reinforced by the widespread perception of technicians as junior professionals. This perception is linked to the value placed on formal knowledge. The notion of a junior professional implies that the technician's identity is subsidiary to and derived from that of the scientist or other professional. The situation is not unlike the predicament faced by wives in the past whose identities stemmed from and worth was measured solely in terms of their husbands' places in society.

Educators, employers, and policy makers must recognize that if they are to gain the benefits associated with adopting skill standards, they may also have to rethink the division of labor in which the skills are embedded. This implies that both schools and employers need to take steps to explicitly recognize that technicians are knowledgeable members of distinct occupations who make unique and important contributions to the production process. What then can employers and schools do?

REQUIRED RESPONSES

What Industry Can Do

Adopting an empirically grounded set of skill standards such as those compiled by the American Chemical Society for CLTs and PTs is a significant first step toward remedying this situation, because such skill standards will help firms distinguish the content of technicians' work from scientists' work. But if technicians are to have their own occupational identity, their expertise must be viewed as more than simply unique. In addition, employers must demonstrate that the technician's expertise is valued, that it will be rewarded, and that it is grounds for respect.

At a minimum, employers must back up demands for skill standards by explicitly acknowledging that technicians have a distinct type of knowledge and that scientists (or engineers) are symbiotically bound to technicians in an interlocking occupational division of labor. Adopting such a rhetoric would not only be more consistent with the expanding responsibilities that firms have begun to expect of technicians, it would also justify changes in human resource policies. For instance, if firms were to discard the language of "junior professionals," they would free themselves to consider alternate career structures for technicians. Rather than require technicians to become scientists to advance, employers could justify instituting "dual ladder" systems for technicians. Traditional dual ladders distinguish technical professionals from managers and enable firms to promote technical contributors who have no interest in supervisory responsibility. The logic of the traditional dual ladder could be easily extended to technicians, whose ladder would parallel the scientist's technical ladder rather than the managerial ladder.

It would be a mistake, however, to view such a system simply as a device for allowing technicians to "advance." To be effective, a dual ladder for technicians would have to rest on substantive distinctions in the work itself. Zabusky and Barley's (in press) research on the careers of technicians indicates that technicians are generally more interested in opportunities for learning and technical achievement than they are in advancement. This suggests that to adequately reward technicians, firms must give more than a general appreciation of technicians' skills. Firms also need to understand how technicians conceptualize technical challenges. With such knowledge, firms can array positions on a technical ladder to make the substantive content and challenges associated with each rung meaningful to the technicians. In fact, if firms better understood technicians' notions of what constitutes interesting and challenging work and how technical skills build on each other, it would be possible to write job descriptions that distinguish between levels of expertise and then link tasks to progressive compensation in ways that would not require the fiction of hierarchical movement. Under such a system, pay would be linked to knowledge, and rewards would be built around opportunities to learn and expand one's skills. Such a model would be more in tune with the craftlike aspects of technicians' work.

Finally, firms could significantly strengthen the technician's occupational identity by actively seeking to strengthen the technician's occupational communities both within and across organizations. Strong occupational communities, such as those characteristic of established professions and crafts, offer several benefits, especially in the long run. Occupations with strong identities and communal structures usually take primary responsibility not only for developing technical knowledge but for training and socializing neophytes. Strong occupational communities also tend to develop cultures of practice committed to skilled performance and high-quality work. Furthermore, strong occupational communities provide an alternative structure for delivering benefits such as health insurance and pension funds. Firms might therefore benefit, even financially, not only from demanding that technicians be more appropriately skilled, but also from recognizing that technicians' skills warrant an occupational mandate and from helping technicians solidify strong occupational identities.

What Educational Institutions Can Do

Educational institutions have three major responsibilities with regard to the education and training of technicians: (1) to provide graduates with the specific skills and knowledge they will need to contribute effectively to the operation of a plant or laboratory; (2) to provide students with sufficient knowledge and skills that will help them throughout their careers; and (3) to provide educational experiences that effectively support the way in which technicians learn. Meeting these responsibilities will be extremely challenging for educational institutions and educators.

Regarding the preparation of students for the workforce, educators have the difficult task of developing curricula that provide the skills and knowledge to support the interlocking work model (Figure 3). The curricula must ensure that students learn skills unique to the occupation of technician and that they obtain the knowledge to use these skills in the context of work being conducted. For example, buffer technicians in the CPI provide scientists and engineers with data used to propose theories, designs, and diagnoses. Working at this interface requires carefully designed instruction that combines knowledge and skills. The skill standards presented in this report provide educators, for the first time, with a validated set of competencies, defined by industry for workers in the industry. The main challenges to the educator are to use this information in the development of curricula and courses for programs in the areas of chemical laboratory and/or process technology and to provide sufficient structure to accomplish all of the requirements in the allotted time.

The development of curricula and instructional material, however, can be the shared responsibility of educators and their industrial counterparts. A description of the concept of forming alliances appears in Section III of this report. To make maximum use of the skill standards in developing curricula and courses, tools have been developed for educators to evaluate current curricula relative to skill standards and to determine at the local level the gap between the skills required by industry and the ability of educational institutions to deliver them. Educational institutions can then use this information to update their programs on an ongoing basis. These tools are outlined in Section III of this report.

For educational institutions to not only prepare students for employment upon graduation, but to provide them with the capability to participate in an ever-changing career, they must respond to rapid technological and social change. Research done as part of the Voluntary Industry Standards Project identified major issues that will affect the career of a technician. A complete description of this work appears on pp. 34 and 35 of this report. Most significantly, evidence suggests that industry will continue to right-size and dependence on contract workers will increase. Both of these trends imply that technicians need to be taught skills that will enable them to be flexible and mobile. To accomplish this, our data indicate that industry requires technicians who are able to solve problems, recognize patterns in data and information, and critically assess workplace needs. To provide this, educators need to design curricula that help students develop analytical skills and critical thinking, which will become part of the way technicians work. Some of these skills will be learned in the context of technical work; others might require courses in other disciplines. Furthermore, educational institutions will be required to move beyond education that stops with a degree or certificate by making continuing, career-long education for technicians a part of the requirement.

By knowing the way in which buffer technicians process information, educators can develop curricula that respond to the needs of those entering careers as technicians and to technicians already in the workplace. Although sufficient research has not been conducted to identify the learning styles of technicians, information is accumulating that shows prospective technicians respond positively to educational programs that include opportunities for contextual learning and for workplace experiences. Programs also need to make effective use of contextual settings to address employability skills such as communication, mathematics, statistics, computer, and teamwork.

Understanding the work of CLTs and PTs in the context of their relationships with scientists and engineers and the availability of skill standards provide a unique opportunity for educators and employers to reassess opportunities that support the technician as a worker and learner.

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SECTION II:
PRESENTATION OF THE VOLUNTARY INDUSTRY STANDARDS

INTRODUCTION

CRITICAL ISSUES AFFECTING CHEMICAL PROCESS INDUSTRIES TECHNICAL WORKERS

CHEMICAL PROCESS INDUSTRIES VOLUNTARY STANDARDS

SKILL STANDARDS: CHEMICAL LABORATORY TECHNICIANS

SKILL STANDARDS: PROCESS TECHNICIANS

BEST COPY AVAILABLE

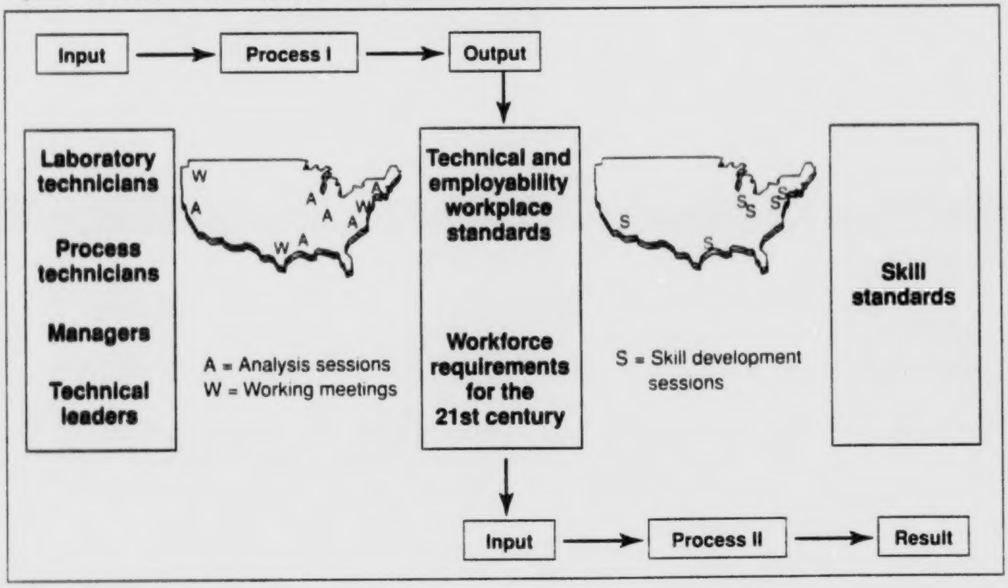
Technical workers for whom the chemical process industries (CPI) skill standards have been developed represent two occupations: chemical laboratory technicians (CLTs) and process technicians (PTs). (PTs are often referred to as process operators within the industry.) To ensure their usability, the skill standards were developed to:

- represent current workplace requirements
- accommodate employability needs into the 21st century
- be adaptable to education and training
- be capable of being implemented at the local level within state frameworks
- be linked to other initiatives

Input on policy and direction was given by the Steering Committee, input on direction and review by the Coordinating Committee, and validation by all concerned parties.

The skill standards development process involved collecting data from CLTs and PTs during *analysis sessions*. The technical and employability workplace standards were derived from the work tasks described at these sessions. During *working meetings*, human resource and technical managers from the CPI provided insight into the workforce requirements of the 21st century and addressed issues that have and will have major impacts on CLTs and PTs. At *skill development sessions*, college faculty and industry training managers used the workplace standards to develop skill standards. Figure 1 depicts the overall process used.

Figure 1. Process for developing voluntary industry standards.


Input
Process I
Output
Laboratory technicians
Process technicians
Managers
Technical leaders
W
A
A
A
W
A
A
W
A
A = Analysis sessions
W = Working meetings
Technical and employability workplace standards
Workforce requirements for the 21st century
S
S
S
S
S
S = Skill development sessions
Skill standards
Input
Process II
Result

The details and results of the two-phase process used to develop the skill standards are included in this section. Specifically, this section contains the critical issues affecting chemical laboratory and process technicians now and in the next century, the process used to develop the skill standards, and the skill standards for chemical laboratory and process technicians.

CRITICAL ISSUES AFFECTING CHEMICAL PROCESS INDUSTRIES TECHNICAL WORKERS

At the onset of the Voluntary Industry Standards Project, the Steering Committee identified four key issues that have a major impact on the development of chemical laboratory technicians (CLTs) and process technicians (PTs) now and in the future. At three facilitated meetings (working meetings), industry leaders responsible for technical and human resource development provided data to clarify the impact of the critical issues on workers. Additional input was provided by the American Petroleum Institute, the Chemical Manufacturers Association, and other industry groups. A total of 256 participants, representing 119 employers, contributed to this effort. These critical issues and their effects on the workforce requirements for the 21st century are summarized on the following pages.

Interface between the Chemist/Chemical Engineer and the Chemical Laboratory Technician/Process Technician

- The work organization will utilize the team approach wherein the interface between the chemist/chemical engineer and the CLT and PT will become less distinct. The roles will be complementary and synergistic.

- CLTs and PTs will be increasingly responsible for determining rewards. This will require a better understanding of success factors for business and knowledge of how jobs add value and contribute to business.

- The enhanced jobs of CLTs and PTs will result in the need for increased skill level and accountability. Entry-level workers will be empowered to contribute beyond required tasks and will be expected to demonstrate adaptability and ability to learn quickly and to communicate effectively.

- CLTs and PTs will be expected to work not only within companies, but with other organizations and with customers.

Industry Trends

- The chemical process industries (CPI) will continue to rightsize, causing continuing uncertainty of workforce stability. This will further the need for CLTs and PTs who have multiple skills and who are adaptable, flexible, and able to accept individual responsibility.

- Employers will require more well-trained individuals from schools and shift away from employer training in fundamentals. This trend will require schools to develop programs with industry that are more responsive to the needs of CLTs and PTs. Industry will rely on contractors and consultants from education to fulfill their training needs.

- More companies will hire CLTs and PTs from contract worker pools, which will result in the need for these workers to develop and maintain skills that are portable.

- CLTs and PTs will be expected not only to work in a defined area, but to contribute in all areas of the laboratory or plant.

- Teamwork is the basis of the new work systems. Developing attitudes consistent with teamwork will be essential for all workers. This will require that educational institutions emphasize participation on teams and self-directed work groups.

- There will be an increased union buy-in to the changing diverse roles of CLTs and PTs.

Technology Trends

- Technology is changing faster than educational systems can adapt. The typical lag time between broad use of a new technology in industry and its inclusion in classroom teaching is four to five years. Cooperative alliances will need to be created between colleges and employers to support the evolving technologies. These alliances will provide:
    - equipment from industry to be used in schools
    - co-ops and internships for students and faculty
    - industrial advisory committees
    - industrial staff as faculty

- Although technology will change, the need for a firm grounding in science with direct applications to work will remain essential for professional survival.

- More complex technology will require greater technical skill for applications such as simulations, electronics, networks, globalization, biological technologies, environmental concerns, safety, distributed computer control, "live" monitoring of processes, and automation.

- As automatic control and robotics technology increases, CLTs and PTs will lose the "feel" for how the processes are working, resulting in the need for increased critical analysis skills to identify and correct problems.

Safety/Health and Environmental Regulations

- Safety/Health and Environmental (S/H/E) regulations will continue to grow, requiring more training and greater personal accountability for technicians. Entry-level employees must:
    - be aware of the need to minimize hazardous wastes
    - be aware of the effect chemicals have on the environment
    - be able to classify chemicals into broad hazard categories
    - have knowledge of broad regulatory issues
    - be prepared to work within safety systems that employers might use

- A lack of qualified instructors and adequate facilities in S/H/E training will require alliances between education and industry to set guidelines for CLT and PT programs.

- Educators will have to learn about and include regulations in the curriculum, and legislation may require training and certification of instructors.

- The number of materials listed as hazardous will continue to increase.

The skill standards presented in this report are organized into major categories of work carried out by chemical laboratory technicians (CLTs) and process technicians (PTs). These categories, called Critical Job Functions, were derived by conducting facilitated analysis sessions during which a modified DACUM process was used. During these sessions, CLTs and PTs provided detailed information about the work they do and the tasks they carry out in conducting the work. Participants were asked to concentrate on work conducted during the early stages of employment, generally the first three to five years. The tasks were then sorted into the Critical Job Functions. Technical workplace skill standards were then developed by combining the tasks and the impact of critical issues to describe the work in terms of the performance required on the job, now and in the future. The technical workplace skill standards were used as the basis for the development of learning strategies for each Critical Job Function. The learning strategies were developed by conducting skill development sessions. Details of the processes used follow.

Analysis Sessions

Eleven analysis sessions were conducted (six for CLTs and five for PTs) in six locations representing various geographical and industrial sectors of the United States. A total of 83 workers participated in these two-day sessions, 53 of whom were CLTs and 30 of whom were PTs. The outcome from these sessions include:

- eight Critical Job Functions for CLTs
- six Critical Job Functions for PTs
- tasks and technical workplace standards for each Critical Job Function
- employability workplace standards for each Critical Job Function categorized as:
  - math and statistics skills
  - computer literacy
  - communication skills

The data from the analysis sessions were validated by more than 500 individuals who, in turn, distributed copies to other workers and groups of workers. All of the information was reviewed, and revisions were made. The results are given in the skill standards presented in this report according to Critical Job Function.

Skill Development Sessions

Skill development sessions were conducted for each of the Critical Job Functions in various locations to provide geographical and industrial diversity. Participants of these two-day sessions were primarily two-year college faculty and industry training managers who attempted to answer the question, "What do students need to learn to master the standards?" These sessions resulted in the development of skill development modules for each of the Critical Job Functions. The skill development modules were further used in the development of learning strategies for CLTs and PTs by two teams: one designated to work on the CLT occupations and one on the PT occupations. Each learning strategy contains the following:

- a statement of importance
- tasks and technical workplace standards
- skill development modules
- contextual examples illustrating how learning is relative to the workplace
- employability skill matrix
- training materials resource database

In all, there are 14 Critical Job Functions with learning strategies containing:

- 113 skill development modules
- 1025 competencies
- 93 contextual examples
- training materials resource database that contains more than 1200 training materials from more than 30 commercial and noncommercial suppliers

A complete list of the meeting locations appears in Appendix F.

SKILL STANDARDS: CHEMICAL LABORATORY TECHNICIANS

The Critical Job Functions for chemical laboratory technicians (CLTs) are:

L1: Working in the Chemical Process Industries

L2: Maintaining a Safe and Clean Laboratory Adhering to Safety/Health and Environmental Regulations

L3: Sampling and Handling Chemical Materials

L4: Measuring Physical Properties

L5: Performing Chemical Analysis

L6: Performing Instrumental Analysis

L7: Planning, Designing, and Conducting Experiments

L8: Synthesizing Compounds

The learning strategies for CLTs were developed by the following team of contributors:

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WORKING IN THE CHEMICAL PROCESS INDUSTRIES

Introduction

The chemical process industries (CPI) are a major part of U.S. business and represent a large diversity of industries ranging from pharmaceuticals to large-scale processing of plastics. Every product a person handles day-to-day has had an origin in the CPI. Chemical laboratory technicians (CLTs) team with scientists in the laboratory to study changes that chemicals undergo to develop new processes and to form new materials to meet changing needs of society and industry. Much of the work involves measuring properties of materials used in chemical reactions and analyzing final products. Technicians must be proficient in handling, analyzing, and synthesizing materials. In addition, they must have the skills to handle complex equipment, to plan and design experiments, and to record and report results accurately. Working in the CPI presents a particular challenge in proper handling of materials, which may range from micro quantities of specialty chemicals to large quantities of commodity chemicals. Of greatest importance are the practices that technicians use to ensure safety in performing their work. Knowing about the industry and the role of the technician is vital to the success and advancement of the technician.

The modules developed for "Working in the Chemical Process Industries" provide the CLT with the knowledge and skills required to understand the business and effectively contribute to the workplace.

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L1
Modules

01 INTRODUCTION TO THE CHEMICAL PROCESS INDUSTRIES 43

02 EMPLOYMENT IN THE CHEMICAL PROCESS INDUSTRIES 45

03 QUALITY IN THE CHEMICAL PROCESS INDUSTRIES 47

04 WORKPLACE SKILLS NECESSARY FOR SUCCESS IN THE CHEMICAL PROCESS INDUSTRIES 49

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INTRODUCTION TO THE CHEMICAL PROCESS INDUSTRIES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Compare the U.S. chemical process industries (CPI) to other manufacturing industries in the United States with regard to capital investment, percentage of gross national product (GNP), number of employees, and other economic factors.

02 List 10 major corporations that are part of the CPI and the major products associated with each.

03 Identify the 20 highest volume chemicals manufactured in the United States.

04 Relate the characteristics and quantity of raw materials used in the CPI to the characteristics and quantity of final products.

05 Describe how the CPI affect the average citizen and contributes to the standard of living.

06 Identify the major business/organization components of a chemical company and describe how they are interrelated (include research, development, processing, manufacturing, marketing, and sales).

07 Discuss current environmental issues associated directly or indirectly with the CPI and identify ways in which the industry is responding.

08 Trace one major product from raw materials to consumer product (e.g., oil to milk containers); identify the job types required to complete this path.

L1.02

EMPLOYMENT IN THE CHEMICAL PROCESS INDUSTRIES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify technical career paths within the chemical process industries and note the position of the technician in that scheme.

02 Discuss the educational preparation required for a variety of jobs, including laboratory technician, process technician, instrument technician, chemist, and engineer.

03 List the types of interest areas, basic skills, personality traits, and work ethic that best fit a career as a technician.

04 Assess local options for employment; list the number who work for industry, for government laboratories, for schools or universities, and for other employers; determine (or estimate) how many of the workers in each category are employed as contract employees.

05 Identify major professional societies associated with the career of a technician and assess the value of participating in local, regional, and national professional societies for a technician.

Recommended Competencies

06 Meet with technicians working in local industry, discuss the kind of work done, and describe the ways technicians contribute to the business.

Careers in the chemical industry can take many different directions and provide unlimited opportunities to anyone willing to build on his or her experience and interests. Entry-level jobs serve as a solid foundation from which individuals can better establish these interests and talents and build a rewarding career. For example, an individual's career began in a research laboratory of a large chemical company. The work was highly technical and changed frequently based on the different research projects that were pursued. After several years, the individual accepted a promotion into a production laboratory. The production lab was very different from the research lab and offered many new challenges. The individual was able to utilize past technical experience for making important decisions quickly, which the production lab demanded. The individual's value was enhanced through continued education under the company education assistance plan. After several years of demonstrating proficiency in the work inside and outside the company, the employee accepted a position in the marketing department of the corporate headquarters. Prior experience in technical and production aspects of the products was invaluable. Customers valued this expertise and, consequently, the employee was able to successfully market the product and have a very positive impact on the company.

QUALITY IN THE CHEMICAL PROCESS INDUSTRIES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe principles of total quality management (TQM).

02 Describe the role of the process technician in implementing TQM.

03 List and define steps involved in problem-solving procedures.

04 Describe elements of TQM as they relate to suppliers, producers, and customers.

05 Draw a process diagram for a chemical operation; identify inputs, process, and outputs.

06 Describe the concept of "continuous improvement."

07 Working with a team, construct a process flow diagram to describe an industrial process or a project or an experiment that is being conducted in the school laboratory.

Recommended Competencies

08 Working as part of a team for a chemical operation, identify those TQM procedures, elements, and principles that contribute to defect prevention.

09 Determine conformance specifications by comparison of inspection done with product specification.

10 Use statistical tools such as fish bone (cause and effect) diagrams, Pareto charts, histograms, and scatter diagrams; demonstrate the use of each and describe the value of each in planning and designing experiments.

L1.04

WORKPLACE SKILLS NECESSARY FOR SUCCESS IN THE CHEMICAL PROCESS INDUSTRIES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Understand the importance of teamwork and have experience working as a member of a team for planning, performing, analyzing, and reporting.

02 Recognize that all members of a team have opinions that must be valued.

03 Demonstrate skill in problem solving.

04 Demonstrate responsibility for fellow workers' health and safety.

05 Demonstrate critical thinking skills.

06 Coordinate several tasks simultaneously.

07 Make decisions based on data and observations.

08 Pay close attention to details and observe trends.

09 Demonstrate high ethical standards in all aspects of work.

10 Apply quality principles to all aspects of work.

MAINTAINING A SAFE AND CLEAN LABORATORY ADHERING TO SAFETY/HEALTH AND ENVIRONMENTAL REGULATIONS

Introduction

Safety/health and environmental (S/H/E) concerns are of prime importance throughout the chemical processing industry (CPI). Chemical laboratory technicians (CLTs) working in the CPI frequently handle hazardous materials and equipment as part of their work. Improper handling can cause major disasters to the environment, other individuals, or the technician. Technicians must be aware that maintaining S/H/E standards is the most important aspect of their work.

Regulations have been developed at federal, state, and local levels, as well as within industry groups and by individual companies, to ensure the safety and health of employees working with materials, others who come in contact with materials during transport, and consumers who use the materials. Regulations address the environmental impact of the chemicals; the processes used to make chemicals; and the transport, storage, and disposal of chemicals. Technicians are often those employees who have the most direct contact with chemicals and related products, and they are responsible for ensuring that S/H/E considerations are addressed appropriately.

To be responsible for handling chemicals, technicians must be knowledgeable about regulations pertaining to the industry and materials with which they work, including reasons for regulations, details of adhering to the regulations, and consequences of not adhering to regulations, including but not limited to personal liability. Technicians must have significant knowledge about chemistry, handling chemicals and equipment, responsibilities of various responses to emergencies, and steps to take in the event of an accident. They must also have the skills required to handle laboratory operations in which either personal or co-worker safety or health is of concern.

The modules developed for this Critical Job Function should prepare students to become technicians with appropriate entry-level skills for these critical areas, having knowledge of S/H/E regulations, and ensure they have the tools to deal with safety in the laboratory and environmental protection. In addition to the appropriate skills, behaviors and values are needed to promote responsible chemical handling.

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TASKS

Tasks conducted by CLTs related to this Critical Job Function include:

- Performing safety inspections.
- Participating in safety audits.
- Participating in S/H/E training.
- Conducting and participating in safety demonstrations, drills, and meetings.
- Using safety monitoring equipment.
- Labeling all chemicals, materials, tools, and equipment with appropriate safety, health, and environmental details.
- Organizing and storing chemicals, glassware, and other equipment properly.
- Keeping laboratories clean and orderly.
- Selecting appropriate safety equipment, including hoods, and using it correctly when conducting laboratory tasks.
- Ensuring that warning labels are displayed appropriately.
- Using ergonomic procedures.
- Reporting and taking action on all unsafe or potentially unsafe conditions and acts.
- Identifying and responding to emergencies, alarms, and any abnormal situations.
- Reporting and taking action on any potential environmental noncompliance.
- Reporting and taking action on any potential health or industrial hygiene problem.
- Encouraging others to act in accordance with good S/H/E standards (providing peer support).
- Disposing of waste chemicals and materials.
- Interpreting material safety data sheets (MSDSs).

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level CLTs are expected to:

- Be aware of and follow federal, state, and local legislation pertaining to environmental, health, and safety regulations; identify their responsibilities under these regulations.
- Recognize that each company has policies and safety plans that include evacuation procedures, emergency numbers, rules, and practices.
- Write a safety plan.
- Be familiar with "Right to Know" legislation and how it applies to CLTs.
- Recognize, apply, and respond appropriately to the hazard symbols and toxicology sections of MSDSs.
- Choose the proper safety equipment for conducting a variety of laboratory tasks (e.g., proper hoods, shields).
- Choose and demonstrate the use of protective equipment to be used in a variety of situations (e.g., eye wear, special clothing).
- Demonstrate safe handling procedures (e.g., handling cylinders, glassware, moving heavy items).
- Apply first aid as needed.
- Use respirators as needed.
- Implement procedures, as part of an organized effort, for handling a neighborhood complaint regarding a real or perceived environmental problem.
- Participate in programs to improve safety.

L2 Modules

01 OVERVIEW OF THE IMPACT OF FEDERAL, STATE, LOCAL, AND COMPANY REGULATIONS AND POLICIES ON THE SAFETY, HEALTH, AND ENVIRONMENTAL CONCERNS OF THE COMMUNITY, WORKER, AND CONSUMER 55
02 THE TECHNICIAN'S ROLE IN IMPLEMENTING REGULATIONS, POLICIES, AND PRACTICES 57
03 DEVELOPING AND EXECUTING A SAFETY PLAN 59
04 PERSONAL AND CO-WORKER SAFETY 61
05 HANDLING LABORATORY EQUIPMENT SAFELY 63

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OVERVIEW OF THE IMPACT OF FEDERAL, STATE, LOCAL, AND COMPANY REGULATIONS AND POLICIES ON THE SAFETY, HEALTH, AND ENVIRONMENTAL CONCERNS OF THE COMMUNITY, WORKER, AND CONSUMER

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify the agencies (federal, state, and local) that develop and enforce regulations pertaining to chemical and related industries.

02 Describe the impact of major regulatory bodies and legislation (e.g., Occupational Safety and Health Administration [OSHA], Food and Drug Administration [FDA], Resource Conservation and Recovery Act [RCRA], Clean Air Act [CAA], and Clean Water Act [CWA]) on the industry.

03 Describe the purpose of the Responsible Care Code developed by the Chemical Manufacturers Association.

04 Specify eight to ten OSHA regulations that are directly applicable to the health and/or safety of the worker.

05 Specify four to six Environmental Protection Agency (EPA) regulations that directly affect the work of the laboratory technician; special attention should be paid to the regulations regarding the handling and disposal of hazardous wastes.

06 Categorize regulations according to those that impact each environmental area (air, water, and noise).

07 Describe the Department of Transportation (DOT) regulations for labeling and shipping hazardous wastes; include the possibility of personal liability.

08 Identify specific state and local regulations that affect operations at local industries.

09 Recognize that companies have specific safety/health and environmental (S/H/E) rules and regulations; review several examples from local industry.

Continued

10 Specify regulations that apply to consumer protection.

11 Use computers to access information about procedures for chemical safety, environmental protection, and health preservation.

12 Read a variety of cleanup and emergency response procedures and determine how to implement the procedures.

Recommended Competencies

13 Describe procedures used to respond to a spill or release.

14 Prepare and present to lay community members clear information about how the industry implements its responsibilities as a good neighbor in the area of S/H/E issues.

Chemical manufacturers have a responsibility to the community and the chemical industry to maintain a safe and clean environment. Manufacturers' compliance with environmental, health, and safety regulations is dependent upon the technician's ability to ensure clean and safe work environmental standards. For example, environmental regulatory agencies cited a pulp and paper mill for polluting a nearby river with dioxin. The community was understandably concerned about the hazards associated with dioxin pollution and threatened to have the plant closed. The plant management was equally eager to address the issue and dispatched a technician to investigate the company's role in the pollution. The technician conducted a thorough analysis for very low levels of dioxin and initially indicated that no detectable amounts of the pollutant came from the plant. To be sure, however, the technician checked the accuracy of the instrumentation, the validity of the samples, and even repeated the analysis a second time. After thoroughly checking the work, the technician concluded, without a doubt, that the dioxin did not come from the plant. The technician's report was accepted by the regulatory agency, which allowed the plant to continue operation and reassured the community that its operations were safe and clean.

THE TECHNICIAN'S ROLE IN IMPLEMENTING REGULATIONS, POLICIES, AND PRACTICES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify the responsibilities of the technician for applying regulatory guidelines in a variety of typical laboratory situations.

02 State the responsibilities and rights of the technician under the Hazardous Communication Standard of the Occupational Safety and Health Administration (OSHA).

03 Apply, by example, the Responsible Care Code as it relates to the laboratory.

04 Identify the conventions and symbols used for labeling chemical materials; include Hazardous Material Identification System (HMIS) and National Fire Protection Association (NFPA) guidelines.

05 Catagorize common hazardous materials as corrosive, flammable, etc.

06 Read and interpret hazard data associated with chemicals that are presented in material safety data sheets (MSDSs) and other chemical data reference documents.

07 Demonstrate the ability to read, interpret, and prepare labels for a variety of chemical materials.

08 Describe appropriate disposal techniques required for each of the categories of common hazardous materials.

09 Identify the requirements for effective response teams and describe the role of such teams in handling emergencies.

10 Demonstrate ability to convert chemical concentrations to different units so that comparison can be made with MSDS safe levels.

Continued

Recommended Competencies

11 Access safety/environmental and health (S/H/E) regulations and data regarding chemicals using references such as CRC Press handbooks, the *Merck Index*, the *Chemical Technician's Ready Reference Handbook*, and MSDSs, as well as by conducting online searches.

12 Visit a local industry and describe the policies and programs that are in place to ensure worker safety.

Safety/health and environmental (S/H/E) regulations are established by federal and state agencies as well as individual plants. Technicians are key to implementing regulations and must therefore have knowledge and understanding of them. For example, a technician working in a lab was asked to produce a particular solvent-borne paint. Because of the hazardous nature of the assignment, the technician referred to the material safety data sheets (MSDSs) required by the Occupational Safety and Health Administration (OSHA). The regulations required that a specific respirator and gloves be used. The technician referred to the OSHA-required labels on solvent and resin containers. The labels provided the technician with identification information and specific usage instructions. The technician followed the requirements and conducted the analyses in a safe environment as a result of implementing the regulations.

L2.03

DEVELOPING AND EXECUTING A SAFETY PLAN

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Specify components of an effective chemical hygiene plan.

02 Test safety equipment in laboratories and maintain a log.

03 List elements of a safety plan for general laboratory safety.

04 Access an emergency response procedure plan from a local industry and discuss the implications for the workers.

05 Develop and deliver a safety awareness session for fellow technicians.

Recommended Competencies

06 Conduct a safety review and audit of a school laboratory by identifying the regulations for the laboratory as if it were in industry, developing or participating in a review team, conducting an audit, identifying areas of noncompliance, and reporting to the group; work with the school staff to correct the items of noncompliance according to a timetable.

Developing and executing a sound safety plan are essential to the daily operations of a laboratory. A safety plan might include regularly scheduled safety discussions, assigning cleaning responsibilities, and/or establishing emergency procedures for laboratory staff. For example, a technician at a university research laboratory was asked to develop and execute a safety plan. As one component of the plan, the technician identified all lab equipment, such as fume hoods, eye washes, and fire extinguishers, that could cause hazards by malfunctioning. The technician created a calendar so that inspections and maintenance could be performed regularly on each piece of equipment. The technician also initiated monthly safety sessions that focused on the proper use of equipment, cleanup, accident prevention, and maintenance. This plan was reliable, inexpensive, and practical and ensured the safety of the laboratory staff.

L2.04

PERSONAL AND CO-WORKER SAFETY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Select and demonstrate the use of appropriate personal protective equipment (PPE) for a variety of situations involving hazardous chemicals, including but not limited to corrosive, explosive, biological, and volatile materials.

02 Demonstrate the appropriate use of safety equipment, including but not limited to safety glasses, showers, respirators, eye washes, and blankets.

03 Demonstrate good housekeeping by maintaining a clean and safe workplace.

04 Demonstrate the ability to perform basic first aid skills.

05 Participate in an evacuation procedure.

06 Prepare and lead a short safety meeting for classmates appropriate to the school setting.

07 Participate in a simulated emergency, both as a leader and as a victim.

08 Participate in a fire safety activity that includes the use of extinguishers to extinguish a variety of fires.

09 Demonstrate proper lifting techniques.

10 Demonstrate proper use of hand tools.

Continued

Recommended Competencies

11 Describe causes of sight and hearing loss in the laboratory environment and identify noise level thresholds requiring protection.

12 Monitor air quality in a workplace (or simulated workplace) using a variety of types of air monitoring equipment.

To ensure a safe working environment, technicians should follow proper procedures and use proper equipment. Lab technicians should always be especially thoughtful of co-workers around them when conducting assignments. For example, a laboratory technician was asked to test solvent bleed resistance of some pigments. Although the laboratory was properly ventilated, it was also small, and solvent fumes could be harmful to anybody in the lab who was not wearing a respirator. The technician informed co-workers of the hazardous nature of the work being carried out and insisted that they use respirators if they chose to stay in the lab. The technician discovered, however, that there were not enough respirators for all of the lab personnel. The technician scheduled the work later in the week and made sure that the proper respirator cartridges were available for anyone who needed them. As a result of careful planning, the tests were conducted safely and with minimal inconvenience to the laboratory.

L2.05

HANDLING LABORATORY EQUIPMENT SAFELY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the purpose of, and handle safely, common chemical laboratory equipment.

02 Store, transport, and change compressed gases cylinders correctly and safely.

03 Choose the proper regulators for gases and other materials under pressure or under vacuum.

04 Manipulate and care for glassware and other apparatus safely, including making connections, cleaning, and storing.

05 Describe how maintenance programs for equipment and laboratory facilities relate to safe and efficient laboratory operation.

06 Identify common components of electrical and electronic circuits that may frequently be maintained by laboratory technicians.

07 Demonstrate a basic awareness of electrical safety and its application to the work environment.

Recommended Competencies

08 Use autoclaves, pressurized reactors, vacuum reactors/separators, closed systems, and a variety of valves for several chemical systems.

Handling laboratory equipment properly can significantly decrease the likelihood of injury. Electrical equipment can be especially dangerous, and precautions should be taken to prevent accidents. Many small electrical components are not designed to operate continuously for long periods of time and can easily overheat, smoke, and catch on fire if they are not monitored. For example, a vacuum pump at a laboratory was inadvertently left running overnight by a technician. During the late night hours, it began to smoke and set off the laboratory smoke alarm. Fortunately, the company security guard was able to respond to the alarm before any damage could be done. Afterward, the technician responsible for the mishap attached a timer to the pump. The timer automatically shuts off the pump after a certain time period and provides assurance that the mishap will not be repeated.

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 66

COMPUTER 67

COMMUNICATION 68

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MATH & STATISTICS

Maintaining a Safe and Clean Lab Environment	MODULES				
	01	02	03	04	05
Calculate Ratios				✓	✓
Perform Unit Conversions		✓	✓	✓	
Calculate Means & Standard Deviations		✓	✓	✓	
Calculate Accuracy & Precision of Data Sets			✓	✓	
Determine Detection Limits			✓	✓	

COMPUTER

Maintaining a Safe and Clean Lab Environment	MODULES				
	01	02	03	04	05
Use a Computer Keyboard	✓	✓	✓	✓	✓
Access Database Information	✓	✓		✓	✓
Develop & Maintain a Database		✓			
Use, Maintain & Develop Spreadsheets			✓		
Conduct On-line Literature Searches	✓	✓			

COMMUNICATION

Maintaining a Safe and Clean Lab Environment	MODULES				
	01	02	03	04	05
Oral Communication	✓	✓	✓	✓	✓
Written Communication		✓	✓		✓
Read & Understand Procedures	✓	✓	✓	✓	✓
Maintain Log & Notes			✓		✓
Keep Records			✓		✓
Give Clear, Concise Instructions			✓	✓	
Report Data			✓		✓
Maintain Accurate Notebook		✓	✓	✓	✓
Read & Prepare Diagrams		✓			
Conduct Literature Searches	✓	✓			
Read Technical Manuals & Journals		✓			✓

SAMPLING AND HANDLING CHEMICAL MATERIALS

Introduction

Chemical laboratory technicians (CLTs) routinely handle chemical materials in all aspects of their work. Handling chemical materials requires special knowledge with regard to potential health and safety hazards that are posed to the worker and the work environment. Handling chemical materials is strictly regulated on the local, state, and federal levels; many of these issues are addressed by the Critical Job Function "Maintaining a Safe and Clean Laboratory Adhering to Safety/Health and Environmental Regulations."

To sample and handle chemical materials properly and safely and maintain the purity and integrity of samples, the technician must have a fundamental knowledge of chemistry and nomenclature.

The modules developed for this Critical Job Function provide for basic chemical principles and nomenclature, which should be supplemented based on local needs. This knowledge is required for classifying chemicals according to hazard potential. A module on sampling is included in this section and can be used in conjunction with the Critical Job Functions "Measuring Physical Properties," "Performing Chemical Analysis," and "Performing Instrumental Analysis."

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TASKS

Tasks conducted by CLTs related to this Critical Job Function include:

- Selecting containers; preparing and storing samples and materials in compliance with both regulations and compatibility.
- Labeling all samples and chemical materials with information containing chemical name, formula, toxicity, date stored, expiration date, appropriate symbols, and other pertinent information.
- Storing samples and chemical materials.
- Preserving materials as recommended, in accordance with material safety data sheets (MSDSs).
- Maintaining inventory, with information regarding expiration, toxicity, etc.
- Developing materials and sampling inventory database and schedule.
- Maintaining inventories within prescribed ranges of quantity and as required to maintain safety and environmental standards.
- Ordering materials as required and evaluating new materials and suppliers when necessary.
- Disposing of materials and samples in compliance with all federal, state, local, and employer regulations.
- Handling hazardous wastes in compliance with all federal, state, local, and employer regulations.
- Preparing samples for shipment in compliance with employer's shipping and receiving rules and regulations.
- Responding appropriately to chemicals spilled in the laboratory.
- Ensuring that appropriate heating, ventilation, and electrical services are used in chemical storage areas.
- Preparing materials for testing and analysis.
- Recognizing hazards associated with handling radioactive materials.

L3 Modules

01 CHEMICAL PRINCIPLES . . . 73
02 CHEMICAL NOMENCLATURE 75
03 HANDLING CHEMICALS SAFELY WITH PROPER HEALTH AND ENVIRONMENTAL CONSIDERATIONS 77
04 HANDLING AND WORKING WITH RADIOACTIVE MATERIALS. 79
05 OBTAINING SAMPLES 81

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level CLTs are expected to:

- Describe characteristics of chemical materials that are applicable to storage and handling (toxicity, health effects, flammability, reactivity, sensitivity, stability, and compatibility with other materials); demonstrate ability to correctly label and store chemicals of all types.
- Use both common and chemical nomenclature for inorganic and organic materials.
- Classify organic and inorganic compounds; write generalized formulas for each of the major classes.
- Write the symbols for the elements and describe characteristics of the common groupings of elements.
- Describe the basic reactions that occur between commonly used chemical compounds.
- Apply federal, state, and local regulations when storing and disposing of chemical materials and waste, and know where to find current information about implementing these regulations.
- Fully understand "Right to Know" legislation and the responsibilities of technical personnel in exercising their rights.
- Prepare materials for proper storage.
- Prepare materials and/or samples for shipment or transport to other laboratories.
- Use proper techniques for storing and transporting gases and other materials under pressure.
- Select and properly handle storage containers for all classes of chemicals and describe potential contamination sources for stored materials.
- Apply knowledge of stability and shelf life to the selection of storage containers and maintenance of chemical inventories and sample libraries.

Continued

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- Design and implement a sample storage system with inventory control.

- Complete and comply with chain of custody, from receipt to disposal of material.

- Know the major use and general characteristics of chemicals used in the industry in which employed.

- Classify chemicals according to reactivity.

- Identify incompatible combinations of chemicals that could result in potentially dangerous situations.

- Identify specific categories of hazardous chemicals.

- Use common chemical reference handbooks effectively and efficiently.

- Know how to access information regarding several types of chemicals.

L3.01

CHEMICAL PRINCIPLES

This module highlights some of the major chemical principles that technicians should know to perform their work. The principles presented here were identified by industry/academic partners as important to the overall knowledge base of the technician. These principles should be reviewed by and augmented by teams consisting of local employer representatives and chemical technology faculty. Modules included in "Performing Chemical Analysis" and "Synthesizing Compounds" expand the knowledge of chemical principles.

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Define "chemistry."

02 Define, differentiate, and give examples of "elements," "compounds," and "mixtures."

03 Define "atoms" and "molecules"; give examples of each.

04 Draw simple atomic structures for several elements; include protons, neutrons, and electrons.

05 Write simple electronic configurations for several elements.

06 Use the periodic table to identify elements and to describe atomic structure.

07 Use the periodic table to characterize elements based on the group.

08 Demonstrate how atoms combine to form molecules.

09 Calculate formula weight.

10 Write and balance chemical reactions.

11 Demonstrate how compounds react with other compounds to form new compounds; relate this to chemical reactions and give several examples.

Continued

12 Describe the concept of stoichiometry as applied to chemical reactions.

13 Describe chemical bonding and bond types, including ionic and covalent.

14 Write the molecular structure of several organic and inorganic compounds using common bond designations.

15 Describe chemical bonding and the relationship of chemical bonding to the physical state of material based on intermolecular bonding; include the concept of hydrogen bonding.

16 Differentiate between organic and inorganic substances; describe characteristics of each.

17 Define "catalyst"; give examples of materials used as catalysts.

Recommended Competencies

18 Give examples of chemical reactions important to local industries that involve catalysts.

19 Predict endo/exothermic characteristics of a chemical reaction.

20 Calculate heat of reaction for several common reactions.

A technician who carries out synthesis needs to understand how unused reactant, product, and byproduct react to be assured of product quality. For example, in a pharmaceutical laboratory, an experienced technician was asked to extract a pure ester compound from a product mixture. To obtain pure product in the most expedient and reliable manner, the technician decided to extract the ester-based product with a base. As a result of understanding chemical principles, specifically acid–base chemistry, the technician conducted the synthesis flawlessly.

L3.02

CHEMICAL NOMENCLATURE

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Use the periodic table to identify and name the elements according to symbol and group.

02 Recognize and name common anions and cations and their charges.

03 Write names and formulas for common inorganic compounds.

04 Write names and chemical structures of common hydrocarbons (aliphatic and aromatic, saturated and unsaturated).

05 Name organic compounds according to functional groups, including:
- ketones
- aldehydes
- alcohols
- ethers
- carboxylic acids
- esters
- amines

06 Use naming systems, including common and IUPAC conventions.

07 Apply various coding systems used for describing the properties of compounds that may be important in hazardous conditions (i.e., Diamond).

Understanding chemical nomenclature and the systems by which chemical elements and compounds are named is essential to the technician's ability to perform tasks optimally. Generally, companies use a combination of the IUPAC system and their own short-hand methods of identifying chemicals. In a laboratory, a technician was given a procedure to make a compound that would eventually be used in new product research of polymer coatings. The procedure called for a compound called "caprolactone," which exists in two forms—gamma and epsilon. Unfortunately, the procedure did not specify which form was to be used. The technician had studied chemical nomenclature and knew that there were two possible forms (each with different ring structures) and that using the wrong caprolactone would yield the wrong product. The technician inquired as to the correct form to use and discovered that the gamma form of caprolactone needed to be used in the procedure. The technician's knowledge of nomenclature clearly saved time and money.

L3.03

HANDLING CHEMICALS SAFELY WITH PROPER HEALTH AND ENVIRONMENTAL CONSIDERATIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Read and interpret standard operating procedures (SOPs) and material safety data sheets (MSDSs).

02 Classify chemicals according to safety and health hazards (flammables, corrosives, oxidizers, and carcinogens).

03 Recognize and handle corrosive materials properly.

04 Use a chemical reference handbook to identify hazards associated with handling and storing chemical materials.

05 Handle and dispose of hazardous materials safely and according to regulatory guidelines.

06 Use mixing techniques appropriate for the materials, specifically when handling acids, bases, oxidizers, and strong reducing agents.

07 Store chemicals appropriately, recognizing the compatibility of the materials being stored and the containers in which they are being stored.

08 Clean laboratory glassware and laboratory equipment made of other materials, using appropriate solvents, detergents, and brushes or cleaning devices.

09 Use appropriate techniques to transfer gases, liquids, and solids from storage containers to equipment used in the laboratory.

10 Prepare the paperwork for ordering chemicals to replenish stock.

Continued

Recommended Competencies

11 On the basis of vapor pressure, assess safe handling procedures for a variety of volatile chemicals.

12 Develop a chemical inventory system for a stockroom that includes all pertinent information regarding stability, hazards, and sensitivity; create a database for the information.

13 Identify heating and ventilation systems used in chemical storage areas and compare their appropriateness for the groups of chemicals being stored.

Working with chemicals, especially unfamiliar compounds, requires special attention to safety, health, and environmental aspects of work. For example, at a research laboratory that develops new film additives, technicians must analyze 20 lot samples (powdered dye colors) every day and determine whether or not they will fit into the product protocol. Before the analysis can be performed, however, many properties of the compound must be determined. Each incoming dry lot sample is labeled with a notebook number, a formula weight, and structure. Because these are new compounds, the hazards are little known. The lab technicians identify the compounds as "respiratory hazard unknown" and "skin hazard unknown." Next, lab technicians analyze several characteristics, including color, physical and chemical properties, and interaction with the product. Ultimately, the data gathered by these laboratory technicians are used to define appropriate hazardous characteristics and ensure safety to future users.

L3.04

HANDLING AND WORKING WITH RADIOACTIVE MATERIALS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Compare hazards associated with various modes of radioactive decay.

02 Apply the concept of half-life to predict potential hazards of radioactive materials.

Recommended Competencies

03 Apply the special requirements for handling and disposal of radioactive materials.

04 Choose proper equipment for monitoring radioactive materials.

05 Calculate half-life of radioactive material using the first-order decay equation.

06 Calibrate equipment used for monitoring radioactive materials.

Radioactive samples are extremely hazardous, which makes sampling and handling them unique; careless sampling and handling can jeopardize work force safety and facility operations. For example, radioactive hazards are common in nuclear power plants. To ensure that the plant is operating as expected, the Nuclear Regulatory Commission (NRC) requires that samples be taken daily from the reactor coolant system and other restricted areas of the plant. To take the samples without endangering the sampling technician or others, protective clothing must be worn. A lab coat, glove liners, rubber gloves, safety glasses, and radiation monitoring meter are absolute necessities for the technician taking the sample. Other precautions are taken as well. The sampling bottle must be plastic to avoid breakage and hazardous leakage. Moreover, the sampling port must be in a stainless steel sink in a hood with lead shielding. After collecting the sample and leaving the contamination area, the protective equipment must be removed and disposed of properly, and the sample must be taken directly to the laboratory. Strict adherence to the sampling procedure is crucial to the health of the technician, the other employees, and the environment.

L3.05

OBTAINING SAMPLES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the importance of obtaining a representative sample.

02 Give examples of some characteristics of solid, liquid, and gas samples that could result in nonhomogeneity.

03 Identify equipment used for sample collection (including thief drum mixing equipment, two-way splitters, and retch samplers) and demonstrate how each is used.

04 Design a sampling scheme to ensure adequate representation from bulk material.

05 Use a variety of grinding, blending, and mixing techniques to prepare homogeneous samples on which to conduct measurements.

06 Identify errors in a measurement that can be attributed to failure to obtain a representative sample.

07 Identify and describe a variety of sample containers and their primary uses.

08 Use sieves to separate a sample according to particle size.

09 Obtain representative samples of gases, liquids, and solids, including:
  - solid materials in bulk storage
  - material in process streams
  - high-vapor-pressure materials
  - corrosive liquids
  - nonhomogeneous solids
  - air- and moisture-sensitive materials
  - materials in environmental (open) systems
  - gases under pressure
  - corrosive liquids
  - micro quantities of liquids and solids
  - biological specimens

Continued

10 Describe potential interactions between the construction materials of a sample container and the contents being stored; identify compatible container materials for common chemicals, solutions, and mixtures.

11 Describe how to store samples to avoid changing their characteristics.

Recommended Competencies

12 Prepare a chain of custody document for a sample taken for analysis.

13 Conduct a statistical analysis to evaluate how well a sample represents bulk material.

Chemical technicians regularly serve as the primary individuals who obtain samples. As simplistic as it may sound, careful and responsible sampling is invaluable. Sampling in the petroleum industry is one example. Thousands of tons of catalyst are used in reactors, which convert crude oil into usable products such as gasoline or ethylene. This catalyst contains platinum, a very expensive noble metal. The value of the catalyst is based strictly on the value of platinum. Platinum catalyst can be used for up to one year, after which, it must be "regenerated." To assess the value of the catalyst after it is removed from the reactor, it is sampled and analyzed. The technician follows the regeneration process from beginning to end, making sure that all procedural steps are taken. In the end, from the tons of material, only six, one-pound bottles of ground material are collected as samples. The results of the technician's analysis of these small but representative portions are ultimately the basis on which the company settles very large financial accounts.

L3

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 84
COMPUTER 85
COMMUNICATION 86

MATH & STATISTICS

Sampling and Handling Chemical Materials	MODULES				
	01	02	03	04	05
Read & Construct Graphs	✓		✓		✓
Calculate Ratios	✓		✓	✓	
Perform Unit Conversions	✓		✓		✓
Perform Calculations Using Exponents	✓			✓	
Perform Calculations Using Logarithms				✓	
Use Appropriate Significant Figures	✓		✓		✓
Recognize Patterns from Data					✓
Solve Single-Unknown Algebra Equations	✓		✓		✓
Calculate Means & Standard Deviations					✓
Calculate Accuracy & Precision of Data Sets				✓	✓

COMPUTER

Sampling and Handling Chemical Materials	MODULES				
	01	02	03	04	05
Use a Computer Keyboard	✓	✓	✓	✓	✓
Access Database Information		✓	✓		
Develop & Maintain a Database			✓		✓
Use, Maintain & Develop Spreadsheets			✓		✓
Use Statistical Software				✓	
Conduct On-line Literature Searches			✓		

COMMUNICATION

Sampling and Handling Chemical Materials	MODULES				
	01	02	03	04	05
Oral Communication	✓	✓	✓	✓	✓
Written Communication	✓	✓	✓	✓	✓
Read & Understand Procedures	✓	✓	✓	✓	✓
Maintain Log & Notes			✓	✓	✓
Keep Records			✓	✓	✓
Write Memos & Letters				✓	
Write Technical Reports					✓
Give Clear, Concise Instructions			✓	✓	✓
Report Data				✓	✓
Maintain Accurate Notebook	✓		✓	✓	✓
Read & Prepare Diagrams	✓	✓	✓	✓	✓
Write Methods					✓
Conduct Literature Searches	✓	✓	✓	✓	✓
Read Technical Manuals & Journals	✓		✓	✓	✓

MEASURING PHYSICAL PROPERTIES

Introduction

Conducting tests that measure physical properties of materials is basic to the job of many chemical laboratory technicians (CLTs). CLTs at all levels require the skills to conduct physical tests. Many technician careers begin in laboratories that measure physical properties. Laboratories where these tests are conducted include, among others, environmental laboratories, quality control laboratories, and product testing laboratories. Such measurements are but a part of all the work performed by laboratory technicians and are often a subset of conducting chemical analysis, conducting instrumental analysis, synthesizing compounds, and planning and conducting experiments. To perform these measurements with competence, the technician must be familiar with the physical nature of materials and the measurement equipment and methods.

Physical properties of materials are often the key product specifications by which chemicals meet the need of the consumer or subsequent user. All chemical materials have specifications such as the formula weight of polymers, boiling point of gasoline, color of dyes, taste of foodstuffs, and smell of fragrances to name a few. The technician must be able to measure each with diligence and care. Technicians must be knowledgeable in the use of statistics, because results are reported in terms of the accuracy and precision of the measurement. The American Society for Testing and Materials (ASTM) is one of many organizations that have developed test methods to be used to measure chemical and physical properties of materials. Procedures must be followed precisely to ensure the validity of measurements on materials. Because the quality of materials, as described by specifications, is the basis of assigning value to a product, technicians must be introduced to the economics of the chemical industry to understand the importance and potential impact of their work.

The modules developed for this Critical Job Function, which address general concepts in measurement, are prerequisites for the Critical Job Functions, "Performing Chemical Analysis" and "Performing Instrumental Analysis."

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TASKS

Tasks conducted by CLTs related to this Critical Job Function include:

- Obtaining representative samples.
- Preparing samples appropriately for tests or analyses.
- Choosing appropriate test equipment to make a required measurement.
- Checking instruments for correct operation.
- Preparing or acquiring calibration standards.
- Calibrating equipment.
- Testing or analyzing control "standard" samples; calculating results and comparing with control values.
- If within statistical range, analyzing samples; if not, troubleshooting causes of error by repeating calibration, instrument check, and maintenance.
- Calculating results.
- Recording and reporting data.
- Cleaning and maintaining apparatus.

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level CLTs are expected to:

- Characterize physical properties of gases, liquids, and solids and describe their reactions to changes of temperature and pressure.
- Choose the appropriate equipment for measuring each of 12 or more major physical properties based on specified accuracy and precision requirements.
- Read, understand, and conduct American Society for Testing and Materials (ASTM) and/or other standard procedures for specific chemical and physical tests.
- Describe how to collect samples to represent bulk materials to be characterized by physical tests.
- Demonstrate the ability to conduct different tests on liquids, gases, and solids that are used commonly in standard procedures.
- Calibrate, calculate results, develop control charts, and determine upper and lower control limits for each.

L4
Modules

01 BASIC CONCEPTS OF MEASUREMENT 91
02 PHYSICAL PROPERTIES OF MATERIALS 93
03 CARRYING OUT STANDARD PROCEDURES 95
04 REPORTING RESULTS ... 97
05 THE RELATIONSHIP OF PHYSICAL PROPERTIES OF MATERIALS TO THE ECONOMICS OF THE CHEMICAL INDUSTRY 99
06 WORKPLACE EXPERIENCE—MEASURING PHYSICAL PROPERTIES . 101

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L4.01

BASIC CONCEPTS OF MEASUREMENT

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the importance of measurement in chemistry.

02 Define "precision" and "accuracy"; provide examples of each.

03 Calculate mean, median, mode, and standard deviation for several data sets.

04 Develop a frequency distribution chart for a data set.

05 Describe a control chart and construct such a chart using a data set.

06 Define what is meant by an "out-of-control" measurement.

07 Define "confidence limit" in terms of standard deviation.

08 Describe what is meant by significant figures; give examples.

09 Compare systematic and random errors.

10 Select and use analytical balances for weighing quantities ranging from 0.001 grams to 100 grams to a specified accuracy and precision.

11 Identify, select, and demonstrate proper use of volumetric glassware (burets, graduated cylinders, flasks, and pipets).

12 Calibrate volumetric glassware.

13 Make quantitative transfers using volumetric glassware.

14 Calculate errors in various measurements based on data acquired using common laboratory equipment.

15 Apply standard rules for determining the number of significant figures in measurements and in the answers to corresponding calculations.

16 Convert units of measure from English to metric and vice versa.

Continued

L4.01

Recommended Competencies

17 Evaluate propagation of error in a calculation involving one or more steps.

18 Calibrate storage containers, safety testing equipment, and air and water monitoring equipment.

Accurately measuring physical properties is a routine but important function of all laboratory technicians. Technicians who use the correct instruments and implement the correct procedures are more likely to yield accurate results. For example, a technician was measuring the specific gravity of a shipment of hydrofluorosilic acid using a standard laboratory procedure. Unfortunately, the technician's result did not agree with the manufacturer's claim of product strength. The technician conducted research to identify the appropriate method for measuring specific gravity and concluded that the existing laboratory procedure was not applicable. The technician identified the correct procedure, remeasured the manufacturer's shipment using the correct procedure, and concluded that the acid was, in fact, of the concentration the manufacturer claimed.

PHYSICAL PROPERTIES OF MATERIALS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe gases, liquids, and solids in terms of their physical properties.

02 Describe how physical properties of materials are related to product specifications and give examples from products that are produced by the local chemical industry.

03 Obtain product specification sheets from local industry and identify the physical properties used as specifications.

04 Describe specifications that are used as process specifications for a variety of processes carried out in the chemical industry.

05 Describe the physical properties listed below; identify kinds of materials on which the property is measured, the units applicable to each, and apparatus and procedures used to make the following measurements:

- boiling point
- formula weight
- cloud point
- odor
- color-optical rotation
- density
- refractive index
- dew point
- particle size
- flash point
- taste
- freezing point
- tensile strength
- hardness
- viscosity
- melting point
- thermal conductivity
- heat capacity
- heats of fusion and vaporization
- colligative properties

Continued

06 For several of the properties in L4.02.05, demonstrate use of appropriate apparatus for making the measurement.

07 Specify the accuracy and precision of analytical equipment used in the measurement of several physical properties in L4.02.05.

08 Calculate volume, temperature, and pressure for gases, using the ideal gas law, Charles's law, and Boyle's law.

Recommended Competencies

09 Describe the effect of changes in temperature and pressure on the physical properties described in L4.02.05.

10 Correlate physical properties of common materials with necessary conditions for storing and handling of these materials.

All materials can be described in terms of their physical properties. Density, color, odor, and melting point are a few examples of physical properties that are recognized by consumers. Technicians who accurately measure physical properties are invaluable to a manufacturer. For example, a technician was asked to evaluate a soft contact lens, a polymeric material, that had been returned by a dissatisfied customer. The product had torn, and it was unclear whether the tearing was a result of poor manufacture or consumer misuse. The technician performed a tensile-strength test, which consisted of pulling a dumbbell-shaped specimen along its axial direction and measuring its elongation as well as the force required to break the material. Additionally, a hardness test was conducted, which indicated the surface stiffness. Ultimately, the interrelationship among the test results indicated to the technician that the product was poorly manufactured. Further discussion with the scientist confirmed this finding, and it was reported to the manufacturer.

CARRYING OUT STANDARD PROCEDURES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Recognize that product specifications are based on the chemical and physical properties of materials and that various organizations provide a variety of standard methods for measuring physical and chemical properties; state the names of the organizations represented by the acronyms and the product area for which they produce methods; the organizations include, among many others:

- USP
- ASTM
- AOAC
- EPA
- IUPAC

02 Describe components of a published method; describe the information contained in each of the components as it applies to safety considerations, equipment, procedural steps, accuracy, and precision.

03 Recognize that procedures published by different organizations are formatted differently but contain similar information; make comparisons.

04 Carry out complete stepwise procedures to measure physical properties of materials of interest to the local industry:

- obtain samples
- set up the required apparatus
- perform calibrations
- perform tests according to procedures
- calculate results
- maintain apparatus in working condition for the next test
- accurately document the complete stepwise procedure(s) performed

Continued

L4.03

Recommended Competencies

05 Given several measurements to be made, choose the most appropriate analytical procedures considering:

- property to be measured
- material to be analyzed
- product specification
- sample size
- sample type
- accuracy/precision required
- selectivity
- sensitivity

Measuring physical properties requires using standardized procedures and following prescribed protocols. The American Society for Testing and Materials (ASTM) and the International Standards Organization (ISO) are two organizations that provide standardized procedures to the chemical industry. Technicians are responsible for understanding these procedures to ensure the safety of the lab and the quality of the work. For example, a chemical laboratory technician was approached by a customer who needed some physical properties tested on a sample of plastic. A request sheet, attached to the sample, specified the desired tests and identified ASTM and ISO procedures. From reading the ASTM and ISO procedures, the technician was able to determine how much sample was required, how the sample needed to be prepared, and what equipment was appropriate. The technician followed the step-by-step procedures in conjunction with existing laboratory protocols and was able to get accurate results for the customer.

L4.04

REPORTING RESULTS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Using data collected from a standard method conducted by several class members, calculate precision and accuracy for several data sets.

02 Present data graphically using a variety of scales and presentation methods.

03 For a multistep procedure, take into account errors in each step and calculate results, expressing answers with appropriate significant figures.

04 Calculate standard deviations at 1, 2, and 3 sigma; describe the significance of each.

Recommended Competencies

05 Identify limiting factors associated with a variety of analytical methods.

06 Using the data collected from a standard method conducted by several class members, prepare control charts and describe the upper and lower control limits and the significance of each.

The solvent industry is highly competitive. Solvent companies are approached daily by businesses demanding inexpensive, high-quality solvents. For example, there are firms that use solvents to remove paint from vending machines. These machines are then refurbished and resold. Clearly, the solvent application is a major component of the business process, and buyers expect the solvent to perform as well in their plant as it does in the solvent manufacturer's lab. The buyers' decision to purchase a solvent hinges largely on a report prepared by a technician. Accurate reporting that reflects comprehensive testing is convincing; sloppy, incomplete reporting can deny the solvent manufacturer the sale. When testing different solvents, the technician must take careful notes and keep accurate records. A summary of the experiments, including narrative, tables, charts, and recommendations, is helpful to the buyer in choosing the appropriate solvent. In the end, a technician who reports accurate results will satisfy the customer.

L4.05

THE RELATIONSHIP OF PHYSICAL PROPERTIES OF MATERIALS TO THE ECONOMICS OF THE CHEMICAL INDUSTRY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Relate how properties of materials have economic impacts on the final product purchased by the customers.

02 Identify physical properties from specification sheets of local industries for a variety of products.

03 Provide examples of how companies handle off-spec material.

Recommended Competencies

04 Calculate economic losses that result from producing materials having off-spec physical properties.

05 Provide examples of how, in a process, the physical properties of a starting material or intermediate affect the products.

Only the safest and most effective products can survive in the marketplace. If a component of a chemical process is even slightly off spec, entire product lines can suffer. Hence, the technician's expertise in measuring physical properties is very important to the economic well-being of the manufacturer. At a manufacturing plant, a mineral oil product was fluctuating in viscosity, although, according to standard operating procedures, the viscosity should have been virtually identical from lot to lot. A technician analyzed samples throughout the manufacturing process in an effort to identify the problem. One sample showed presence of a rare nonpathogenic species of bacteria that had adapted itself to the conditions of the process. A team of plant personnel decided that to find the bacteria's breeding ground, the plant had to stop manufacturing the product and run the manufacturing process using only purified water. The technician again analyzed the process and ultimately identified certain pieces of equipment that provided a safe haven for the bacteria. The technician's ability to convincingly provide the support for this conclusion saved the manufacturer a great deal of time and a large sum of money.

L4.06

WORKPLACE EXPERIENCE—MEASURING PHYSICAL PROPERTIES

To develop the necessary skills required to measure physical properties it is important that the technician spend time in the laboratory and work as a team member with senior technicians involved in measuring physical properties.

Upon completion of this module, the technician will be expected to:

Recommended Competencies

01 Observe the work and interpersonal relationships in one or more industrial quality control or product quality laboratories.

02 Relate the work of the laboratory to the remainder of the company.

03 Work under the supervision of a senior technician and measure several physical properties, carrying out the following steps:
- obtain and read standard methods of analysis
- obtain samples and ensure that they are representative
- prepare the necessary equipment to achieve appropriate accuracy
- prepare or obtain standards
- calibrate the equipment
- conduct the test
- calculate the result(s)
- report the results with appropriate significant figures and a statement of precision and accuracy

04 Prepare a report on physical property measurements, including principles on which the tests are based, conclusions, next steps, and recommended follow-up.

L4

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 104
COMPUTER 105
COMMUNICATION 106

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88

MATH & STATISTICS

Measuring Physical Properties	MODULES					
	01	02	03	04	05	06
Read & Construct Graphs	✓	✓	✓	✓		✓
Calculate Ratios	✓	✓	✓	✓	✓	✓
Perform Unit Conversions	✓	✓	✓	✓		✓
Perform Calculations Using Exponents	✓		✓	✓	✓	✓
Perform Calculations Using Roots	✓		✓	✓	✓	✓
Perform Calculations Using Logarithms			✓	✓		✓
Use Appropriate Significant Figures	✓	✓	✓	✓	✓	✓
Recognize Patterns from Data	✓		✓	✓		✓
Solve Single-Unknown Algebra Equations	✓		✓	✓		✓
Solve Simultaneous Equations			✓	✓		✓
Solve Quadratic Equations			✓	✓		✓
Calculate Means & Standard Deviations	✓		✓	✓		✓
Calculate Accuracy & Precision of Data Sets	✓		✓	✓	✓	✓
Determine Control Limits	✓		✓	✓		✓
Determine Detection Limits			✓	✓		✓

COMPUTER

Measuring Physical Properties	MODULES					
	01	02	03	04	05	06
Use a Computer Keyboard	✓	✓	✓	✓	✓	✓
Access Database Information	✓	✓	✓	✓	✓	✓
Develop & Maintain a Database	✓	✓	✓	✓	✓	✓
Use, Maintain & Develop Spreadsheets	✓	✓	✓	✓	✓	✓
Use Graphics Software	✓		✓	✓		✓
Use Microprocessors			✓	✓		✓
Use Statistical Software	✓		✓	✓		✓
Transfer Data to & from Remote Databases			✓	✓	✓	✓
Conduct On-line Literature Searches		✓	✓		✓	✓

COMMUNICATION

Measuring Physical Properties	MODULES					
	01	02	03	04	05	06
Oral Communication	✓	✓	✓	✓	✓	✓
Written Communication	✓	✓	✓	✓	✓	✓
Read & Understand Procedures	✓	✓	✓	✓	✓	✓
Maintain Log & Notes	✓		✓	✓	✓	✓
Keep Records	✓		✓	✓	✓	✓
Write Memos & Letters	✓	✓	✓	✓	✓	✓
Write Technical Reports			✓	✓		✓
Give Clear, Concise Instructions			✓	✓	✓	✓
Report Data	✓	✓	✓	✓	✓	✓
Maintain Accurate Notebook	✓	✓	✓	✓		✓
Read & Prepare Diagrams	✓		✓	✓	✓	✓
Write Methods		✓	✓			✓
Conduct Literature Searches		✓	✓		✓	✓
Read Technical Manuals & Journals	✓	✓	✓		✓	✓

PERFORMING CHEMICAL ANALYSIS

Introduction

Performing chemical analysis is critical to the development and professional advancement of all chemical laboratory technicians (CLTs), most of whom will be expected to perform chemical analyses as their primary function early in their careers.

The study of chemical analysis provides a context for understanding many basic concepts of chemistry (e.g., writing and balancing equations, handling materials, preparing reagents, kinetics, chemical equilibrium, and pH). Because samples often need to be separated into various specific components or otherwise conditioned before analysis, concepts of chemical separation are included.

In conducting chemical analyses, technicians use most of the common volumetric glassware associated with laboratory operations. Instrumental methods are included in the chemical analysis section where they measure chemical reactions such as in colorimetry and electroanalytical methods.

In "Performing Chemical Analysis," technicians must pay specific attention to principles of measurement, sampling, and validity of data. Modules on measurement and sampling are included in "Measuring Physical Properties" and "Sampling and Handling Chemical Materials" and, if not covered previously, should be included in work done in association with this module.

The modules developed for this Critical Job Function define chemical analysis as measurements based on the chemical reactivity of the material being analyzed. More common chemical reactions are acid–base, oxidation–reduction, complex formation, precipitation, and those that produce spectrally sensitive compounds. Other analytical techniques involving membranes, enzymes, etc., are not specifically addressed here but might be included as local objectives based on the need of employers.

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TASKS

Tasks conducted by CLTs related to this Critical Job Function include:

- Obtaining representative samples.
- Making observations regarding condition of sample and recording any notable characteristics.
- Responding to problems by reading test documents or procedures and implementing appropriate information.
- Identifying appropriate equipment for the analysis to be conducted.
- Gathering, cleaning, and calibrating all necessary glassware, reagents, chemicals, electrodes, and other equipment required to carry out the specified analysis.
- Preparing and standardizing any required reagents.
- Preparing samples for analysis (dissolve, digest, combust, ash, separate interfering material, etc.).
- Analyzing standards or control samples using specified techniques.
- Recording data and, if within limits, proceeding to analyze sample.
- Calculating results to appropriate significant figures.
- Recording data and presenting results, as appropriate, for single samples and for multiple samples to display trends.
- Evaluating analytical results and responding appropriately.
- Identifying conditions that indicate need for an analysis to be repeated.
- Recording and reporting data.
- Maintaining laboratory work areas and returning all equipment and materials to original storage locations.
- Modifying or developing analytical methods to be appropriate to necessary test methods, required analyses, the implementation of personnel qualifications, and working environment where methods are to be used.

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level CLTs are expected to:

- Use basic analytical chemistry procedures and concepts of measurements applicable to volumetric, gravimetric, colorimetric, spectrometric, chromatographic, and electrochemical techniques.
- Use a variety of sampling procedures and select the proper procedure to sample a bulk material.
- Prepare samples for analysis, including digesting, ashing, dissolving, grinding, and removing impurities as appropriate before analysis.
- Use standard separation techniques, such as ion exchange, column chromatography, and thin-layer chromatography.
- In conducting volumetric analysis, use and select indicators; select and use standards; select and prepare solutions; and use, select, and care for electrodes for acid–base, redox, and complexometric titrations.
- Balance chemical equations involving acid–base, redox, and other chemical reactions.
- Calculate and measure pH using both wet and instrumental methods.
- Calculate normality, molarity, and molality of solutions, given the chemical formula and the reaction for which the solution is to be used.
- Prepare and standardize acid and base solutions of different concentrations (molarity and molality).
- Conduct analytical tests using acid–base, oxidation–reduction, and complexometric titrations.
- Conduct colorimetric and spectrophotometric analyses and apply Beers's law for calculating results.
- Select techniques and devices for colorimetric analyses appropriate for specific samples and accuracy requirements.

Continued

L5
Modules

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- Calibrate a colorimetric procedure to the required degree of accuracy.

- Select filtering media for specific uses.

- Conduct a variety of gravimetric analyses and demonstrate capability to follow procedures and produce accurate results at the required levels.

- Use several electrochemical techniques.

- Locate and apply specified information in several standard procedural manuals and books, including those produced by the American Society for Testing and Materials (ASTM), the Association of Official Analytical Chemists (AOAC), other groups that produce "standards," and government agencies that issue and/or monitor regulations.

In addition, technicians working in research and development laboratories will be expected to be experienced in analyzing unknown materials, including identifying interfering materials, modifying analytical procedures, and developing new procedures for chemical analysis.

L5.01

CHEMICAL PROPERTIES OF MATERIALS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Define and give examples of chemical properties of materials.

02 Describe chemical reactivity by writing and balancing equations involving
- neutralization reactions
- displacement reactions
- oxidation–reduction reactions
- complexometric reactions

03 Describe and write chemical reactions that can be characterized by the intensity of the color they form.

04 Describe and write chemical reactions that form insoluble precipitates.

05 Describe an electrochemical cell and show the reactions that take place on the anode and cathode.

L5.02

READING ANALYTICAL METHODS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify and describe specific sections of published standard methods, including scope, detection limit, equipment, safety considerations, calibration, procedure, precision, accuracy, and results format.

02 Read a reference method used by a local employer; identify the scope, equipment safety considerations, calibration, required procedure, precision, accuracy, and results format; note differences among methods used by local employers, industry, and comparable standard methods in reference books.

Recommended Competencies

03 Identify associations that develop and evaluate analytical methods for chemical analysis such as the American Society for Testing and Materials (ASTM), the Association of Official Analytical Chemists (AOAC), and the U.S. Pharmacopeia (USP).

04 Use printed and on-line techniques to identify appropriate analytical methods for specific analytical requirements.

05 Write an analytical method containing all of the components used in standard methods.

Standard analytical methods can be viewed as "legal" procedures that must be followed to ensure that a product manufactured in a chemical plant meets the specifications by which it will be sold to the customer. Hence, technicians with the role of determining product quality indeed carry a great deal of responsibility for the manufacturer. In the manufacture of a pesticide, a particular cholinesterase inhibitor (the mechanism by which pesticides in the herbicide category work) was measured using a colorimetric procedure. The technician applied a standard method and reported the results. The technician followed all of the steps in the procedure and was confident of the results. When the herbicide was tested, however, it did not respond as expected for the concentration as measured. After investigation, it was determined that the measurement was slightly out of range for the method as written. Carefully addressing the details of methods is critical to the validity of the technician's results. In this case, having more carefully read and understood all components of the method would have prevented the time lost in testing.

L5.03

PREPARING ANALYTICAL SOLUTIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Compare formula weight to equivalent weight for several compounds, given the acid–base or oxidation–reduction reaction in which they are involved.

02 Calculate mole quantities and equivalent quantities for given quantities of materials.

03 Define "solution concentration" in terms of mass/volume, normality, molarity, and molality and describe the experimental conditions when each concentration unit is appropriate.

04 Calculate the amount of material required to prepare specified amounts of solutions of known molarity and molality, given the formula weight of the material.

05 Calculate the amount of material required to prepare specified volumes of solutions of specified normality, given the equivalent weight and/or the reaction for which the solution will be used (acid–base titrations, oxidation–reduction titrations).

06 Calculate the volume of a solution of known normality required to produce a specified volume of a solution of lower normality.

07 Prepare solutions of required normality, molarity, and molality to be used for a variety of measurements, including acid–base and oxidation–reduction titrations.

08 Define "primary standard" and give examples.

09 Standardize solutions of known concentrations (normal, molar, and molal) using appropriate primary standards.

When performing analytical procedures involving titration, the solution used as the titrant is the basis on which the result is calculated. Preparing the titrant accurately is critical to the work of the technician who is carrying out chemical analyses involving titrations. The concentration of the titrant is always based on the chemical reactions involved in the measurement. Normal solutions are prepared by first determining the reaction that is taking place. A technician using sulfuric acid as a titrant must determine the number of sulfuric acid protons that are involved in the reaction with the material being analyzed. The concentration of hexamine diamine (HMDA), a monomer in the production of nylon, is measured using a titrimetric procedure. Using a diprotonic acid, such as sulfuric acid, in a reaction involving only one proton requires the technician to calculate the concentration on that basis; failure to do so results in an error by a factor of 2. Errors in judgment regarding the preparation of analytical solutions can be costly.

L5.04

PREPARING SAMPLES FOR CHEMICAL ANALYSIS I— GETTING SAMPLES INTO THE REQUIRED FORM

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe characteristics of acids and bases with respect to their behavior (corrosivity, handling procedures, etc.).

02 Demonstrate proper techniques for pouring acids and bases and mixing them with other materials.

03 Use techniques such as grinding and mixing to obtain a homogeneous sample and cite the advantages and disadvantages of the tools and techniques used in these operations.

04 Transfer liquids, solids, and gases from bulk containers to labware used for analysis.

05 Carry out the following techniques to prepare samples for analysis and describe the appropriate use of each:

- grind solid materials using a mortar and pestle, a ball mill grinder, and a hammer mill grinder
- dissolve samples in aqueous and nonaqueous solvents
- acid digest samples
- ash samples in porcelain and platinum containers
- reflux materials

Recommended Competencies

06 For each of the above sample preparation techniques, give an example of a specific analytical method that requires use of the technique.

07 Prepare a presentation on a sample preparation technique, the type of materials it is to be used on, and analytical methods for which it is most appropriate.

Continued

L5.04

Oftentimes, to perform a chemical analysis, the chemical in question must be converted into a different form. Chemicals may have to be ground in a blender, dissolved in a solvent, or heated to a gaseous state to conduct the analysis. A technician who pays special attention to procedure, accuracy, and precision enhances the credibility of the analysis. For example, a pharmaceutical firm produced a product in tablet form. To test the product, however, the sample needed to be in powder form. The tablet replicates were carefully ground into powder form, sampled, weighed, and assayed according to the standard laboratory procedure. Unfortunately, the composite results were not always reproducible. As a matter of fact, the ground sample was not homogeneous. The technician determined that these inconsistent results were because either the chemical was changing properties when it was ground into powder, an inhibitor was interfering with the analysis, or the sample was not representative of the entire tablet. The technician reviewed notes, procedures, equipment, and instruments and discussed the situation with supervisors and colleagues. As a result of this research, the technician concluded that a different testing method was necessary for this product. Together with lab scientists, the technician developed a new method of testing by which the entire tablet was used. As a result, the new method reduced human error, cut sample preparation time, and significantly improved reproducibility.

PREPARING SAMPLES FOR CHEMICAL ANALYSIS II—ISOLATING THE MATERIAL TO BE MEASURED

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the use of the following separation techniques used in chemical analysis:
- filtration
- distillation
- evaporation
- extraction
- column chromatography
- ion-exchange chromatography
- size exclusion chromatography
- electrophoresis
- thin-layer chromatography

02 Compare the behavior and role of stationary and mobile phases in column chromatography.

03 Demonstrate how to use column chromatography to isolate components and prepare samples for analysis.

04 Isolate components of mixtures using several techniques described in L5.05.01.

05 Give examples of analytical applications for each of the isolation techniques described in L5.05.01.

Recommended Competencies

06 Select chromatographic column packings based on the polar and nonpolar characteristics of the material to be separated.

07 Prepare a table that includes 10 separation methods and examples of the use of each in conducting chemical analysis.

Continued

L5.05

Most components laboratory technicians measure in a lab are not received in clean bottles of relatively high purity. Instead, they come in matrices of all shapes and sizes. A technician might be asked to measure one component in a complex material mixture of similar composition—a specific dye, for example, in a garment of clothing or the DNA content of a speck of blood found on a car seat. One such example occurred when a technician in a major food company received the pancreas of a rat and was asked to analyze for a specific compound from a foodstuff that might have been concentrated there. Without disturbing the integrity of the target material, the technician had to prepare the material in such a fashion that it was homogeneous, isolate the ingredient by extracting it into an appropriate solvent, and finally carry out the analysis. The steps taken to isolate the material of the compound being measured were critical in determining the amount of the compound remaining in the pancreas of the animal. Such analytical steps are essential for a chemical company to provide assurance that the products it manufactures are safe for humans, and they underscore the key role played by the laboratory technician in preparing samples.

L5.06

MEASURING pH

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Relate the pH scale to acidity/basicity.

02 Calculate pH given the H^+ or OH^- concentration.

03 Calculate H^+ or OH^- concentrations given the pH.

04 Calibrate a pH meter.

05 Measure pH using indicators, papers, and pH meters; graphically compare each method.

06 Describe the process by which buffers work and their use.

07 Control pH by using buffers.

08 Clean and store pH electrodes correctly.

09 Correct for the effect of temperature on the measurement of pH.

Recommended Competencies

10 Measure pH in nonaqueous solutions.

11 Measure pH using an on-line pH meter.

One of the most widely measured properties in the chemical industry, pH is used to control reactions and measure product quality in almost all aspects of the business. Thus, technicians who measure pH are gatekeepers in quality control. In the multimillion-dollar electronics industry, chemical reactions play a key role in circuit board manufacturing. To create ubiquitous contact points on circuit boards, perforated laminated boards are dipped into a hot bath of plating material. The depletion of plating material from the bath is reflected in the change in pH. In one case, a technician noticed that the pH of the plating bath was different from the pH of the laboratory sample. The technician's initial investigation suggested that the discrepancy was due to a difference in temperature between the manufacturing bath and the laboratory sample. Despite the use of a temperature correction probe, however, the technician still could not account for the discrepancy. The technician was very confident in the pH measurements; earlier, the technician had conducted calibrations and noted accuracy and precision. When the technician shared the results with the laboratory scientists, they recognized specific and familiar characteristics of temperature-sensitive reactions. Further research concluded that the problem was a result of the formation of a reversible complex that formed at the temperature of the bath. The technician's ability to know, with confidence, the accuracy of the pH measurements led to the significant finding.

L5.07

PERFORMING VOLUMETRIC ANALYSIS I—ACID–BASE TITRATIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write and balance acid–base neutralization reactions.

02 Relate the number of protons involved in neutralization to the calculation of equivalent weight.

03 Standardize solutions of known normality to be used as titrants for specific reactions.

04 Select and use specific indicators to be used for acid–base titrations.

05 Select the appropriate electrodes for acid–base titrations.

06 Using indicators, perform standard procedures involving acid–base titrations.

07 Using electrodes, perform standard procedures involving acid–base titrations.

08 Read end points from electrode potential curves.

09 Demonstrate how to care for and condition electrodes.

10 Plot electrode potential curves from a data set collected during a titration.

Recommended Competencies

11 Use an automatic titrator and compare the data obtained with a manual titration.

12 Perform titrations in nonaqueous media.

13 Identify electrodes to be used in nonaqueous solvents.

Continued

14 Prepare and use buffer solutions to control pH for acid–base systems.

15 Measure the rate of a neutralization reaction by carrying out an acid–base titration.

16 Perform acid–base titrations to measure components specific to local employer needs.

Chemical reactivity based on acid or base concentration is widely used in the chemical industry. Technicians are often called on to monitor whether a reaction has been completed or whether specifications have been met based on titration to measure the acid or base concentration of an intermediate or product. A very small chemical company developed a terpene-based cleaner that was safer to use than fluorocarbon-based products it had previously been using. The process by which the new cleaner was made was one of simply blending drums of two materials together. In a control lab, a technician titrated a sample of the blend to determine the acceptable alkalinity before the product could be shipped. If a product does not meet the specifications, the material must be discarded. Nonshipment of manufactured product costs a company a great deal of its profit, a result particularly harmful to a small company. The skill of the technician in performing the acid–base titration is essential in ensuring the reliability of the results.

L5.08

PERFORMING VOLUMETRIC ANALYSIS II—OXIDATION–REDUCTION TITRATIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe how oxidation–reduction titrations are used for chemical analysis and give examples.

02 Apply the oxidation states of common ions in writing chemical formulas.

03 Write and balance oxidation–reduction reactions.

04 Write oxidation and reduction half-reactions in terms of loss and gain of electrons.

05 Use redox potentials to predict the outcome of an oxidation–reduction reaction.

06 Describe characteristics, use, and care of electrodes used in oxidation–reduction titrations.

07 Write chemical equations for reactions occurring on the electrode surface.

08 Perform standard procedures involving oxidation–reduction titrations.

Recommended Competencies

09 Perform oxidation–reduction titrations by measuring components specific to local employer needs.

Chlorine is used in the treatment of municipal drinking water supplies to remove bacteria. The residual chlorine in the water affects the taste and smell. Residual chlorine is a test carried out by technicians working at municipal water treatment facilities. Keeping the chlorine content within the part-per-million (ppm) specification range is critical to the successful operation of the plant. The technician uses the principles of oxidation–reduction to measure the chlorine in the water. Acetic acid and potassium iodide are used to reduce the chlorine to chloride, in turn oxidizing the iodide to iodine. The iodine is then quantitatively reduced to iodide by titrating with sodium thiosulfate. The ppm residual chlorine is calculated by combining the reactions. In measuring the residual chlorine, the technician obtained an unusually high result. The technician knew by experience that if the chlorine content were indeed as measured, there would have been a noticeable smell of chlorine. By making this observation, the technician postulated that something in the water was contributing to the high result. By understanding the chemistry of the method, the technician recognized that an interfering substance entered into the oxidation–reduction reaction with the acetic acid and potassium iodide. Further investigation determined that an impurity was present in a batch of reagent used in the analysis, and the water met the specifications for municipal drinking water.

L5.09

PERFORMING VOLUMETRIC ANALYSIS III—COMPLEXOMETRIC TITRATIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe how complexometric titrations are used in chemical measurement and give examples.

02 Write chemical equations for complexometric titrations.

03 Describe the characteristics, use, and care of ion-selective electrodes.

04 Perform standard analytical methods using EDTA.

Recommended Competencies

05 Write chemical equations for chelation and identify the chelating agents.

06 Write reactions involving EDTA when used as a chelating agent.

07 Perform procedures involving complexometric titrations to measure components of interest to local employers.

Laboratory technicians perform complexometric titrations as a routine part of their job. For example, to prevent corrosion and buildup, water is passed through water-softening cartridges before being used in a boiler. A technician conducted complexometric titrations to measure the effectiveness of the treatment. Repeated titrations confirmed that the water in the boiler was hard. The technician performed some calculations and decided to replace the cartridges. With the new cartridges in place, the technician performed the complexometric titration again and found the measurements to be within reasonable range. Conducting such complexometric tests and making sound decisions based on accurate results extended the life of the expensive boiler.

PERFORMING COLORIMETRIC ANALYSIS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify components of a colorimeter and spectrophotometer.

02 Describe how colorimetric analysis is used for chemical measurements and give examples.

03 Relate wavelength, frequency, and color for the visible spectrum as used in chemical measurements.

04 Apply Beers's law to the measurement of concentration and describe the function of absorbance, path length, and extinction coefficients in such measurements.

05 Carry out absorbance/transmittance conversions.

06 Determine the working range for colorimetric measurements and give examples.

07 Select and use standards appropriately to calibrate for colorimetric analyses.

08 Determine the detection limit for a specific colorimetric analysis.

09 Perform several standard analytical procedures using colorimetric methods.

Continued

L5.10

Recommended Competencies

10 Select manual and automatic scanning instruments based on their limitations and capabilities for providing measurements appropriate to the chemical systems involved.

11 Select, use, and care for cells for gases and liquids.

12 Calibrate a colorimetric technique using internal standard techniques.

13 Follow written procedures for colorimetric analysis, including sample preparation and calibration, and use colorimetric analysis to measure components of interest to local industry.

By the very nature of the industry, countless measurements are made each day based on the reactive properties of materials. In the fertilizer component of the chemical industry, product is sold based on nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) content. The purchase of a 5–10–5 fertilizer buys a product equivalent to 5% N, 10% P_2O_5, and 5% K_2O. In the manufacture of fertilizer, the composition of the product is measured by determining and controlling the percentage of each of these elements. The N exists not as nitrogen, but as nitrate or urea or some other nitrogen-containing compound; the phosphorus exists not as elemental phosphorus, but as phosphate, usually added as phosphate rock that is treated with H_2SO_4 or HNO_3 to give a phosphoric acid equivalent; and the potassium exists as potash. During the manufacture of a complex fertilizer, a technician in a control lab is required to measure the phosphate content in a blend. Because acidic phosphate compounds can exist as mono-, di-, or triprotonic acids, the technician must be able to write the reactions and balance the equations before conducting the vanadomolybdophosphoric acid colorimetric method. In this method, the orthophosphate reacts under acid conditions to form a heteropoly, molybdophosphoric acid. In the presence of vanadium, a yellow color is formed. Iron, if present in concentrations greater than 100 mL/L, causes a positive interference. By not understanding the full context of the sample being analyzed, a technician can cause costly errors.

L5.11

PERFORMING GRAVIMETRIC ANALYSIS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe how gravimetric analysis is used in chemical measurement.

02 Identify chemical reactions that produce precipitates that may be used as analytical methods for several types of chemical materials.

03 Based on particle size retention, select filter media (e.g., paper, cellulose acetate, glass fiber, millipore, and nucleopore) as appropriate to specified chemical systems.

04 Use laboratory apparatus such as a variety of filters and centrifuges to effect quantitative separations and retentions.

05 Perform several multistep gravimetric procedures, including sample collection, preparation, cleanup, analysis, data collection, and calculation of results.

Recommended Competencies

06 Relate solubility product constants to the effectiveness of chemical precipitation for analytical measurements.

07 Perform a gravimetric analysis by measuring components specific to a local employer's needs.

Precious metal analysis of reforming catalyst is performed by manufacturers and purchasers so that they can agree upon financial settlement. To use an instrumental method to conduct the assay, it is critical that calibration be carried out with standards that have been assayed by gravimetric methods. For the gravimetric determination of platinum, a chemical laboratory technician must perform an 18-step procedure in which 40 grams of the alumna-based catalyst containing 0.3% platinum is digested with phosphoric and hydrochloric acids; the platinum is precipitated with mercurous chloride and then reprecipitated. Finally, the residue is ignited and pure platinum is weighed to within +/– 0.0001 grams. This catalyst can be used as a standard to calibrate the instrumental techniques.

L5.12

PERFORMING ELECTROANALYTICAL TECHNIQUES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe how electroanalytical techniques are used in making measurements on chemical systems.

02 Describe the relationship of Faraday's law to concentration.

03 List and describe characteristics of a variety of electroanalytical methods of analysis, including coulometry, polarography, and electrophoresis.

04 Balance oxidation–reduction reactions by writing half-reactions.

Recommended Competencies

05 Describe measurable electrochemical properties of materials that are useful for chemical analysis.

06 Use electrolytic cells to conduct measurements on solutions.

07 Conduct electroanalytical measurements using polarography, coulometry, electroplating, or other related techniques.

08 Select and use ion-selective electrodes for measurement of cations or anions.

09 Perform an electroanalytical procedure to measure components specific to a local employer's needs.

Since the early 1800s, knowledge of chemistry and knowledge of electricity have advanced hand in hand, and electroanalytical techniques have come to figure importantly in analysis. For example, a technician was applying electroanalytical techniques using an ion-selective electrode (ISE) to determine nitrate content at a fraction of the part-per-million (ppm) level. The company for which the technician was conducting the analysis had claimed a detection limit of 0.1 ppm nitrate, but the technician's results were indicating otherwise. The technician had difficulty obtaining reproducible results within the manufacturer's claimed limit. Over a period of two months, the technician carried out experiments as suggested by the manufacturer's technical services personnel. Despite the efforts of the technician, the 0.1 ppm level could not be substantiated, and the manufacturer conceded that the 0.1 ppm detection limit was not practical. Meanwhile, a new detection limit of 0.5 ppm proved to be within linear range. The technician's clear understanding of electrochemical techniques was essential to this important finding.

L5.13

THERMODYNAMICS AND KINETICS IN ANALYTICAL CHEMISTRY

This module requires a basic understanding of:

- *why reactions take place*
- *role of catalysts in chemical reactions*
- *heat of reaction—Hess's law*
- *half-reactions*
- *chemical bonding*
- *bond energies*
- *dissociation constants*
- *Gibbs's free energy*

Upon completion of this module, the technician will be expected to:

Recommended Competencies

01 Describe rate of reaction and give examples of methods to control rate.

02 Provide examples of chemical reactions that take place in local industries and describe the parameters that influence the rate of these reactions and how they are controlled.

03 Control chemical reactions by applying qualitatively the concepts associated with chemical kinetics and thermodynamics.

04 Select and control chemical reactions based on their thermodynamic behavior, particularly endothermic and exothermic characteristics.

05 Perform reactions that require environmental control because of atmospheric, reactivity, or toxicity conditions (using dry boxes, glove boxes, hoods, etc.).

L5.14

WORKPLACE EXPERIENCE—
CHEMICAL ANALYSIS

To develop the skills necessary to perform chemical analysis, it is important that the technician spend time observing and working in a laboratory where chemical analyses are performed.

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Meet with technicians and scientists and have them describe the importance of chemical analyses to the objectives of their laboratory and/or employer.

02 Describe how the laboratory is organized to conduct chemical analyses safely, effectively, and efficiently.

03 Identify glassware and equipment used in the laboratory and compare with comparable glassware and equipment used in the school laboratory.

04 Conduct, under the direct supervision of senior technicians, standard analytical procedures using two or more of the following:

- acid–base titration
- colorimetric analysis
- electrochemical procedures
- complexometric procedures

05 Write the relevant chemical equations for the analytical procedures carried out; document procedures used to obtain proper samples, prepare the samples, standardize the necessary solutions, perform appropriate calibrations, and carry out the measurements; determine the precision and accuracy of each measurement; and prepare a report.

Recommended Competencies

06 Review job descriptions of technicians conducting chemical analyses.

EMPLOYABILITY WORKPLACE STANDARDS

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MATH & STATISTICS

Performing Chemical Analysis	MODULES 01	02	03	04	05	06	07	08	09	10	11	12	13	14
Read & Construct Graphs					✓	✓	✓	✓	✓	✓	✓	✓		✓
Calculate Ratios			✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Perform Unit Conversions			✓				✓	✓	✓	✓	✓	✓		✓
Perform Calculations Using Exponents						✓				✓		✓	✓	✓
Perform Calculations Using Roots						✓						✓	✓	✓
Perform Calculations Using Logarithms						✓							✓	✓
Use Appropriate Significant Figures							✓	✓	✓	✓	✓	✓		✓
Recognize Patterns from Data				✓			✓	✓	✓					✓
Solve Single-Unknown Algebra Equations			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Solve Simultaneous Equations										✓	✓	✓	✓	✓
Solve Quadratic Equations													✓	✓
Calculate Means & Standard Deviations			✓			✓	✓	✓	✓	✓	✓	✓		✓
Calculate Accuracy & Precision of Data Sets		✓	✓			✓	✓	✓	✓	✓	✓	✓		✓
Determine Control Limits		✓	✓			✓	✓	✓	✓	✓	✓	✓		✓
Determine Detection Limits		✓	✓			✓	✓	✓	✓	✓	✓	✓		✓
Measure Rate													✓	

COMPUTER

Performing Chemical Analysis	MODULES													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Use a Computer Keyboard				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Access Database Information		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓
Develop & Maintain a Database													✓	✓
Use, Maintain & Develop Spreadsheets						✓	✓	✓	✓	✓	✓	✓		✓
Use Graphics Software											✓	✓		✓
Use Microprocessors										✓		✓		✓
Use Statistical Software						✓	✓	✓	✓	✓	✓	✓	✓	✓
Transfer Data to & from Remote Databases						✓	✓	✓	✓	✓	✓	✓		✓
Conduct On-line Literature Searches		✓				✓	✓	✓	✓	✓	✓	✓		✓

COMMUNICATION

Performing Chemical Analysis	MODULES													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Oral Communication				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Written Communication		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Read & Understand Procedures		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Maintain Log & Notes			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Keep Records			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Write Memos & Letters														✓
Write Technical Reports														✓
Give Clear, Concise Instructions														✓
Report Data			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Maintain Accurate Notebook			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Read & Prepare Diagrams			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Write Methods						✓	✓	✓	✓	✓	✓	✓		✓
Conduct Literature Searches		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Read Technical Manuals & Journals		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓

PERFORMING INSTRUMENTAL ANALYSIS

Introduction

Proficiency in conducting instrumental analysis is critical to the success of the chemical laboratory technician (CLT). Instruments are used in all areas of the chemical industry and in every chemical laboratory. Technicians are expected to choose the instrument appropriate for a given analysis; know the limitations of the instrument; properly prepare samples for the required analysis; calibrate the instrument; apply proper safety precautions to all instrumental techniques; and, upon entering the workforce, apply company-specific methods for instrumental analysis. Entry-level technicians should have had experience performing common instrumental methods and developing simple procedures using the various techniques. Performing instrumental methods using American Society for Testing and Materials (ASTM), Association of Official Analytical Chemists (AOAC), and other published procedures is a requirement of most technicians within their first year of employment.

The importance of specific techniques will vary with the specific employer; thus, students should be familiar with all common instruments, with concentration in the instrumental areas most pertinent to local requirements. Calibration, sample preparation, safety, use of references (both paper and electronic), range limitations, instrument limitations, and maintenance apply to all techniques.

The modules developed for this Critical Job Function include use of the most common instruments. Technicians who have been trained adequately in several instrumental techniques are likely to make the necessary translations from one instrumental technique to another. Technicians must be comfortable using instruments, including observing deviations from normal operations; troubleshooting; making simple repairs; making judgments regarding the relationship of the sample to analysis parameters; and communicating with scientists, instrument technicians, and service organizations. Colorimetric analysis, an instrumental technique, is included in Critical Job Function L5, "Performing Chemical Analysis," because the formation of color and its intensity is based on chemical reactions.

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TASKS

Tasks conducted by CLTs related to this Critical Job Function include:

- Obtaining representative samples.
- Determining appropriate treatment of the sample before conducting an analysis.
- Preparing a sample for analysis according to specifications.
- Selecting the analytical instrument to be used as appropriate to the results needed and other constraints.
- Starting up instrument by checking all connections and gas cylinders and implementing procedures to ensure reliable results.
- Setting all the instrumental parameters properly using manual and/or program microprocessor settings.
- Calibrating and standardizing equipment and materials as appropriate.
- Developing necessary calibration charts.
- Analyzing standards and control materials.
- Evaluating results of testing or analyzing standards and control materials.
- Adjusting operating parameters as necessary.
- Conducting analyses.
- Reviewing and interpreting results.
- Recording results with appropriate detail.
- Reporting results as appropriate.
- Identifying the need for and performing routine maintenance as required.
- Shutting down instrument and cleaning up work area.
- Maintaining and/or ordering spare parts necessary to ensure consistent operation.

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level CLTs are expected to:

- Apply basic knowledge of organic and inorganic chemistry, including nomenclature, classification in chemical groups, chemical and physical characteristics of bulk quantities, and chemical reactivity with common reactants (water, oxygen, etc.), to instrumental analysis.

- Apply basic concepts of spectroscopic analytical methods and demonstrate application of spectroscopic techniques to the analysis of materials.

- Apply the basic concepts of chemical/physical separation techniques and apply separation techniques to the analysis of materials.

- Apply the principles of a variety of calibration techniques, including standard calibration and internal calibration, for a variety of principal components and matrices.

- Choose appropriate sample preparation techniques for physical characterization measurements and/or analysis of structure, concentration, and composition.

- Troubleshoot problems common to analytical instruments.

- Interpret and use schematic and electronic diagrams and drawings describing instruments.

Molecular Spectroscopy

- Describe the common features of structural analysis of inorganic and organic materials (e.g., crystallinity, functional groups, bonding).

- Apply the principles of infrared (IR) spectroscopy and apply the technique to determine the presence of major organic functional groups.

- Interpret simple IR spectra.

- Calibrate, operate, troubleshoot, and maintain the different types of infrared instruments and select the instrument most appropriate to a required analysis.

- Apply principles of nuclear magnetic resonance (NMR) and use typical NMR instrumentation to determine structure (characteristic use of NMR instruments and interpretation of spectra would be made appropriate to local needs).

Continued

L6
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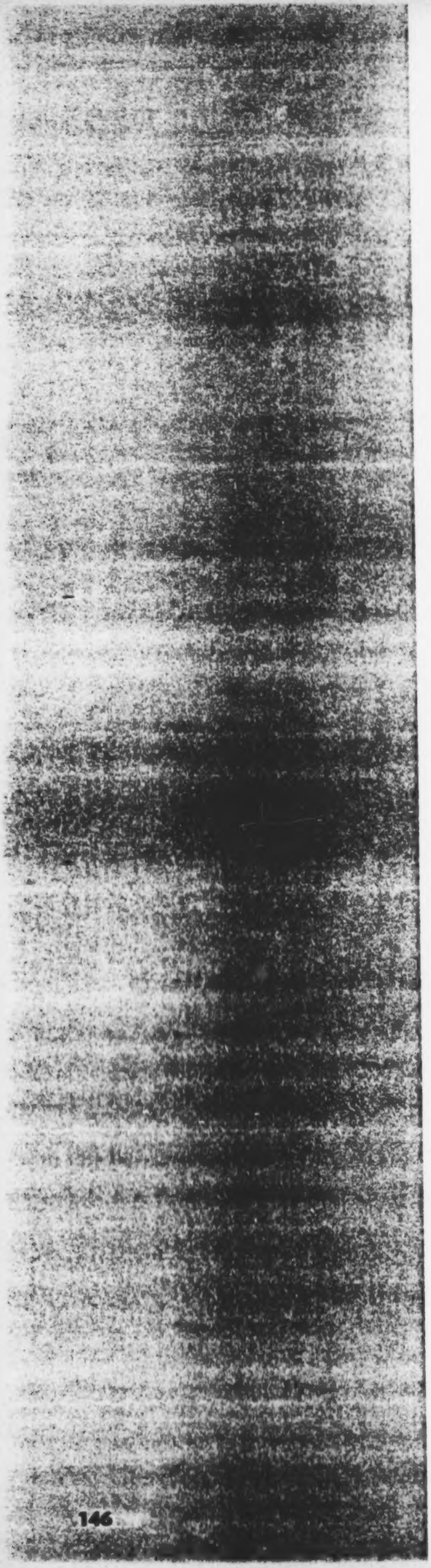

Atomic Spectroscopy

- Apply principles of atomic absorption (AA) spectroscopy and typical AA instrumentation to calibrate, operate, troubleshoot, and maintain AA instruments (characteristic use of AA instruments and interpretation of data would be made appropriate to local needs).

- Apply principles of emission spectroscopy and typical emission instrumentation to calibrate, operate, troubleshoot, and maintain emission instruments (characteristic use of emission instruments and interpretation of data would be made appropriate to local needs).

- Apply principles and types of X-ray fluorescence and, if available, set up, calibrate, and use an X-ray fluorescence instrument.

Chromatography

- Describe principles of gas chromatography (GC) and typical GC instrumentation and demonstrate ability to calibrate, operate, troubleshoot, and maintain GC instruments (characteristic use of GC instruments and interpretation of data would be made appropriate to local needs).

- Identify, prepare, and use columns and related instrumentation for the separation of mixtures of different materials used by local employers.

- Apply principles of high-performance liquid chromatography (HPLC) and typical HPLC instrumentation to calibrate, operate, troubleshoot, and maintain HPLC instruments (characteristic use of HPLC instruments and interpretation of data would be made appropriate to local needs).

- Apply principles of thin-layer chromatography (TLC) and typical TLC instrumentation to calibrate, operate, troubleshoot, and maintain TLC apparatus and instruments (characteristic use of TLC and interpretation of data would be made appropriate to local needs).

X-Ray Diffraction and Microscopy

- Apply principles of X-ray diffraction and typical X-ray diffraction instrumentation, as applicable, to determining structure (characteristic use of X-ray diffraction instruments and interpretation of data would be made appropriate to local needs).

Technicians working in research and development laboratories will require in-depth experience and knowledge in all techniques listed above. In addition, the technician should use the following methods to choose the techniques required to analyze unknown materials and to develop methods as required.

L6.01

OVERVIEW OF INSTRUMENTAL ANALYSIS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Recognize that instrumental analysis can be divided into four major categories and give examples of each:
- molecular spectroscopy
- atomic spectroscopy
- chromatography
- X-ray diffraction and microscopy

02 Describe for the following instrumental techniques the basic theory of operation, terms associated with each, how each is applied in solving problems, and limitations of each:
- molecular spectroscopy
  - -ultraviolet–visible (UV–vis) spectrometry
  - -infrared (IR) spectrometry
  - -mass spectrometry (MS)
  - -nuclear magnetic resonance (NMR)
- atomic spectroscopy
  - -X-ray fluorescence
  - -emission spectroscopy
  - -atomic absorption (AA) spectroscopy
- chromatography
  - -gas chromatography (GC)
  - -high-performance liquid chromatography (HPLC)
  - -thin-layer chromatography (TLC)
- X-ray diffraction and microscopy

03 Use print media, computer software, and libraries to obtain relevant spectra, structure, and other reference data; show how each is used in solving problems.

L6.02

TROUBLESHOOTING AND MAINTENANCE

This module is intended to be used in conjunction with the modules that address the specific instrumentation. It is designed for laboratory technicians, not maintenance or instrumentation technicians.

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Read and understand instrument manuals and follow manual directions appropriately.

02 Recognize whether instruments are working properly; develop a sense that spectra or other outputs are consistent with normal operations; identify signs of degradation and impending failure.

03 Read instrument diagrams and identify warnings and cautions.

04 Apply basic knowledge of electronics and electronic systems for troubleshooting instruments.

05 Make minor repairs, change fuses, locate failing electrical connections, and identify likely points of electrical failure.

06 Identify when a problem with an instrument requires the service of an instrument repair technician.

07 Maintain an equipment log for instruments in the laboratory.

08 Use tools appropriate to instrument maintenance, including pipe fitting.

Continued

L6.02

Recommended Competencies

09 Troubleshoot root causes of problems; isolate single variables.

10 Identify instrument malfunctions that occur at computer interfaces.

11 Recognize details of a service maintenance contract and the associated vendor relationships.

12 Recognize patterns in data obtained from an instrument.

During routine sample analysis, technicians must be on the lookout for unusual results. For example, a technician running a high-performance liquid chromatography (HPLC) assay on a bulk drug stability sample followed instrumentation and set up requirements outlined in the testing protocol. When a standard sample was injected onto the system, however, the resulting chromatogram showed a split peak. The chromatogram should have shown a Gaussian peak. The technician immediately prepared another standard solution, injected it into the column and, once again, observed a split peak. The technician was confident that the standard solution was correct and decided to research troubleshooting HPLC systems. The research suggested that some of the packing material in the column might have disintegrated. The technician removed the column fitting and frit to find that some of the packing had indeed disintegrated. The technician replaced the damaged column, injected the standard solution, and observed a Gaussian peak. The technician returned the defective column to the manufacturer and continued the analysis.

CALIBRATION

This module is intended to be used in conjunction with modules that address specific instrumental techniques.

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the use of calibration techniques when performing instrumental analysis.

02 Perform calibrations using available instruments and plot appropriate graphs.

03 Identify the linear portion of a calibration curve.

04 Describe the causes of nonlinearity in calibration.

05 Describe the importance of matrix correction in calibrating instrumental techniques; give specific examples for at least one instrumental technique in each of the following categories: molecular spectroscopy, atomic spectroscopy, and chromatography.

06 Use computers to prepare graphs and other calibration descriptions.

07 Describe limitations of instrumental techniques based on matrix effects, interferences, etc.

08 Define the concept of "extrapolation to infinite dilution" and its use in calibration.

09 Perform a calibration using standard additions and describe the value of the technique.

The ability to calibrate equipment is a standard skill requirement for any laboratory technician. Laboratories applying for International Standards Organization (ISO) 9000 certification must maintain records that show calibrations have been properly carried out. These calibrations should be traceable back to standards of organizations such as the National Institute of Standards and Testing (NIST). Technicians, therefore, need to be accurate when conducting calibrations and to keep good records when performing calibrations.

L6.04

SAMPLE PREPARATION

This module is intended to be used in conjunction with the modules that address specific instrumental techniques.

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify and describe at least four different methods used for preparing samples for instrumental analysis.

02 Identify the appropriate solvent for a variety of materials being analyzed, consistent with the technique being used.

03 Identify grades and specific characteristics of reagents, including citing specific characteristics required of spectrograde reagents.

04 Demonstrate proficiency in handling small quantities of materials.

05 Handle moisture-sensitive materials in a dry box.

Recommended Competencies

06 Demonstrate ways to protect samples from contamination or alteration.

07 Extract materials from a variety of matrices using liquid/liquid and solid/liquid techniques.

Technicians should understand the importance of preparing samples in conjunction with using equipment and instrumentation appropriately. For example, a technician was conducting an analysis of known and unknown samples using a Rainin Pipet-man pipettor. To use the Rainin Pipet-man pipettor, samples must be diluted to fall within a linear range of the assay. The technician conducting the analysis did not dilute the samples correctly, and the instrument produced results that appeared to be inconsistent. The technician asked for, and received, training on preparing samples. When the technician applied this new skill to the analysis, the results were consistent and highly accurate.

L6.05

PRINCIPLES OF SPECTROSCOPY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Define "spectroscopy" in terms of the interaction of radiant energy and matter.

02 Draw a diagram of the electromagnetic spectrum indicating wavelength regions from gamma rays to radio waves.

03 Identify wavelength and frequency ranges of ultraviolet (UV), visible, and infrared (IR) regions.

04 Show the relationship among wavelength, frequency, and energy and the inverse proportionality between frequency and wavelength.

05 Diagram energy-level transitions observed by the absorption of radiation and those by the emission of radiation.

06 Describe differences between the way energy is absorbed in the IR region and the ultraviolet–visible (UV–vis) region of the spectrum.

07 Show the relationship between concentration of an absorbing species and the transmittance or absorbance of energy.

L6.06

MOLECULAR SPECTROSCOPY I—
ULTRAVIOLET–VISIBLE SPECTROSCOPY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify ultraviolet (UV) and visible portions of the spectra.

02 Using Beers's law, solve equations relating concentration to spectral absorbance in the UV and visible ranges.

03 Sketch a simple diagram of a spectrometer used for UV analysis; identify the radiation sources and the detectors used.

04 Describe the kinds of compounds that absorb in the UV region of the spectra.

05 List major analytical applications of UV spectroscopy.

06 Demonstrate proper care of cells used for analysis.

07 Carry out several analyses using UV absorption; follow through from calibration to final analysis on known materials.

08 Provide examples of uses of ultraviolet–visible (UV–vis) spectroscopy in local industry.

Ultraviolet spectroscopy is a specifically sensitive technique for measuring polynuclear hydrocarbon aromatics (PNAs). Because the PNAs are considered carcinogenic, they are strictly regulated, and technicians making these measurements must exercise extreme care in handling samples. Additionally, highly purified solvents must be used to extract the PNAs from the organic materials where they might be present. These factors pose many challenges for a technician performing the technique. For example, a technician was conducting an analysis and noted variable results. After some discussion with the laboratory scientist, it was determined that the standard materials were light sensitive and were being degraded. The technician suggested that they change the light in the work space to yellow. When the lighting was changed, the standard remained stable, and the measurement for PNAs was carried out successfully.

L6.07

MOLECULAR SPECTROSCOPY II— INFRARED SPECTROSCOPY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify the infrared (IR) portion of the spectrum in terms of frequency range.

02 Solve equations relating concentration to absorbance (Beers's law).

03 Write a description of the principles of IR spectroscopy (see L6.01).

04 Identify the functional groups most appropriately measured using IR spectroscopy.

05 Describe how IR spectroscopy is applied to analysis of materials and to the identification of functional groups.

06 Properly handle and care for IR sample cells.

07 Identify common IR detectors and describe the use of each.

08 Identify instrumental parameters associated with IR spectroscopy and their impact on measurement.

09 Identify limitations of IR spectroscopy as a technique.

10 Prepare samples for IR analysis using mulls, pellets, reflectants, salt plates, and liquid sampling cells.

11 Calibrate an IR instrument for a specific analysis (see L6.03).

12 Analyze several known samples using IR techniques.

13 Provide examples of uses of IR spectroscopy in local industry.

Continued

L6.07

Recommended Competencies

14 Describe the difference between wavelength dispersive IR and Fourier transform IR (FTIR) spectroscopy.

15 Describe common mechanisms of interfacing IR apparatus with other instruments.

16 Identify major vendors of IR equipment (Perkin-Elmer, Nicolet, etc.).

17 Select the most appropriate IR spectrophotometric technique for a given analysis.

18 Use a computer to access reference spectra.

Laboratory technicians who are knowledgeable about infrared (IR) spectroscopy can identify unknown solids, liquids, or films. Unlike other techniques, IR spectroscopy analyzes the way in which specific wavelengths of IR energy excite molecular vibration and rotation. For example, a technician was asked to explain why heat-sealing bags were not sealing properly. Using IR spectroscopy, the technician analyzed several samples and noticed a difference in the coating of the failed bag sample versus the coating of the functional bag sample. The IR technique indicated that the coatings on the bags, applied to prevent the bags from sticking together, were in different structural forms. It was clear to the technician that the coating on the failed bag sample was interfering with the sealing process. The technician notified the supplier of the problem, and new raw material specifications were written.

L6.08

MOLECULAR SPECTROSCOPY III—MASS SPECTROMETRY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of mass spectrometry (MS) and diagram the components of a mass spectrometer (see L6.01).

02 List uses of MS as an analytical tool.

03 Describe the concept of a parent ion and its importance in mass spectra-analysis.

04 Identify a variety of MS techniques (e.g., ionization, time of flight).

05 Explain how vacuum systems work in MS systems.

Recommended Competencies

06 Give examples of how various instruments such as liquid chromatographs and gas chromatographs are combined with mass spectrometers to form liquid chromatography/MS and gas chromatography (GC)/MS techniques.

07 Prepare samples for MS analysis.

08 Predict the mass spectrum for a specified sample mixture.

09 Analyze a variety of materials using a mass spectrometer.

10 Identify parent ions from a mass spectra output.

11 Provide examples and uses of mass spectrometers in local industry.

Technicians can generate unwanted side reactions when synthesizing a novel compound. Mass spectrometry (MS) is often used to monitor the completion of reactions. The entire mixture can be analyzed directly, separated in time by using on-line gas chromatography (GC), or used in conjunction with liquid chromatography. In addition to the proper operation of a variety of mass spectrometers and chromatographs, the technician must be able to interpret resulting spectra. The presence of product and product-related ions must be verified, and the identity of the side products should at least be assigned. Knowledge of organic structures and how they behave in a mass spectrometer is essential. This information is essential for the synthetic chemist to understand how to modify the chemistry to produce the desired product.

L6.09

MOLECULAR SPECTROSCOPY IV—
NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of nuclear magnetic resonance (NMR) spectroscopy (L6.01).

02 List uses of NMR as an analytical tool.

03 Identify structural properties of materials measured using NMR.

04 Describe hazards associated with working with NMR.

05 Provide examples of uses of NMR by local employers.

Recommended Competencies

06 Tune and calibrate an NMR instrument.

07 Prepare samples for NMR analysis.

08 Perform analyses using proton and ^{13}C NMR instruments.

09 Interpret basic patterns of spectra.

10 Use and explain why and when deuterated solvents are used for NMR experiments.

11 Identify major vendors of NMR instruments.

12 Provide examples and uses of NMR as a measurement tool in local industry.

Nuclear magnetic resonance (NMR) spectroscopy is widely used in industry to confirm chemical structure of compounds synthesized for new products. Good instrumental skills and accurate interpretation of NMR data are crucial in this process. For example, a chemist synthesized a compound that was to be used in a new skin care product. Before the compound could be used, however, NMR analysis needed to be carried out. Using standard methods, the technician dissolved the sample in an appropriate deuterated solvent and measured the proton and carbon NMR spectra. After carefully interpreting these results, the technician determined that the data were consistent with the proposed structure. Because of the technician's careful analysis, the chemist was assured that the compound could be formulated into a new product.

ATOMIC SPECTROSCOPY I— X-RAY FLUORESCENCE

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of X-ray fluorescence (see L6.01).

02 Describe how X-ray fluorescence is used to analyze for elements and give specific reasons why one would choose this technique over others.

03 Describe why the nondestructive nature of X-ray analysis makes it a valuable analytical technique.

04 Calculate X-ray intensity relative to concentration and wavelength using the Bragg equation.

05 Identify and describe safety considerations and regulations associated with using X-ray equipment.

Recommended Competencies

06 Identify and describe the types of X-ray fluorescence techniques (wavelength and energy dispersion) and the principles by which each works.

07 Conduct an analysis of a known material using X-ray fluorescence, which includes calibration, matrix correction, sample preparation, and calculation of percentage of component element.

08 Conduct an analysis on an unknown material using X-ray fluorescence.

09 Provide examples of at least four ways in which X-ray analysis is used in industry.

Continued

L6.10

A major chemical company was testing the effectiveness of a catalyst, which consisted of chromium on an aluminum base. A technician in an elemental analysis laboratory was asked to develop a method that would monitor the effectiveness of the catalyst in the pilot plant test at the 1% level. Using a standard wet chemistry method, the technician used a colorimetric method to measure chromium at the 1% level within +/– 0.01% and at the 95% confidence level. Because samples were taken every hour from the pilot plant, the technician decided to use X-ray fluorescence. The technique was calibrated using the catalyst measured by colorimetry as a standard. Unfortunately, the initial measurements using the X-ray technique could only be made to +/– 0.05%, which was not sufficiently precise to be used to monitor the test. Upon investigation, however, the technician discovered that the moisture content of the material used to calibrate the X-ray method varied significantly. The technician knew that varying moisture content can cause a large deviation in test results. The technician changed the calibration material to one that did not vary in moisture content and made subsequent measurements using the X-ray technique to +/– 0.005%. By understanding the X-ray fluorescence technique, the technician was able to test the catalyst effectively and efficiently.

L6.11

ATOMIC SPECTROSCOPY II— EMISSION SPECTROSCOPY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of emission spectroscopy (see L6.01).

02 Describe principles of emission spectroscopy that make it useful as an analytical tool.

03 Characterize energy sources used to excite materials, including spark source, flame, and inductively coupled plasmas; explain the use of each.

04 Identify precautions required for handling high-energy sources safely.

05 Identify and describe the various detectors associated with emission spectroscopy instruments.

Recommended Competencies

06 Conduct (or observe someone conducting) analyses using emission spectroscopy.

07 Relate fundamentals of atomic structure and spectral lines resulting from excited states to the use of emission spectroscopy as an analytical tool.

08 Provide examples of at least three applications of emission spectroscopy in industry.

Emission spectroscopy is a technique often used by technicians to troubleshoot problems resulting from contamination. For example, a sample of stainless steel, showing signs of corrosion, was submitted to a chemical technician for analysis. The technician subjected the sample to a spark that, in turn, identified the spectra of the composite steel. The technician compared the spectra to a control sample of stainless steel and concluded that the vanadium concentration in the sample was higher than that of the control sample. The technician double-checked the work and then passed the results back to the engineering staff, who were able to find the source of error and correct the manufacturing problem.

L6.12

ATOMIC SPECTROSCOPY III—ATOMIC ABSORPTION

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of atomic absorption (AA) spectroscopy (see L6.01).

02 Describe principles of AA that make it useful as an analytical tool.

03 Compare a variety of AA techniques commonly used in industry, including flame, graphite furnaces, and vapor generation.

04 Describe principles of operation of hollow cathode tubes and how they are used to perform analyses.

05 Identify requirements for calibration and corrections for interference for elemental analysis using AA.

06 Use an AA method to analyze an element in a mixture, including sample preparation, dilution, calibration, analysis, and calculation of results and accuracy.

Recommended Competencies

07 Conduct analyses using AA for both single- and multielement analysis.

08 Provide examples of at least four applications of AA in local industry.

Atomic absorption (AA) spectroscopy is one of many ways to conduct elemental analysis. For example, a community organization had implemented a paint recycling campaign. To comply with health and environmental regulations, the donated paint had to be analyzed for lead content. To expedite the analysis, a lab technician chose to screen materials by AA. By diluting the paint and running AA analysis, the technician could quickly, inexpensively, and safely determine lead content.

L6.13

CHROMATOGRAPHY I—GAS CHROMATOGRAPHY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of gas chromatography (GC) as a separation tool (see L6.01).

02 Identify uses of GC as an analytical tool.

03 Identify the components of a gas chromatograph.

04 Relate retention time and resolution to the characterization of mixtures.

05 Identify detectors, including thermal conductivity, flame ionization, and electron capture in terms of their use, detection limits, and special characteristics; list advantages and disadvantages of each.

06 Relate the effects of column length to separation.

07 Install and maintain a variety of chromatographic columns, including capillary, glass, etc.

08 Identify and describe characteristics of a variety of column types in terms of packing material and construction material, with emphasis on packed vs. capillary columns.

09 Use a variety of gas chromatographs to analyze known and unknown mixtures by applying the following procedures:
- prepare samples
- dilute samples as appropriate
- select column packing
- choose injection temperature
- choose column length
- adjust flow
- condition columns
- calibrate instrument
- optimize conditions
- identify the components in a mixture
- calculate the percentage of the components in the mixture
- repeat the analysis
- calculate the precision of the measurement

Continued

L6.13

Recommended Competencies

10 Identify and describe a variety of column packings in terms of their polarity and phases and describe when to use each.

11 Characterize a variety of injection ports and the usefulness of each for gases and liquids.

12 Operate a computer-controlled gas chromatograph.

13 Identify major vendors of gas chromatographic instruments.

14 Provide examples of at least six applications of GC in local industries.

Gas chromatography (GC) is a convenient means to obtain a lot of information about liquid materials. The information generated by modern GC instruments can be used by virtually all sectors of research, product development, and troubleshooting. For example, a technician was given a sample of gasoline that was not performing properly in an automobile. The technician injected the sample of gasoline into a heated port of the chromatograph and measured the resulting peaks. The technician compared a standard sample of fuel with the fuel in question and concluded that the peaks were higher in the poorly performing fuel, indicating higher boiling components. This was a clear explanation as to why the fuel was performing poorly, and the results ultimately traced the problem to the service station at which the fuel was sold.

L6.14

CHROMATOGRAPHY II—
HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of high-performance liquid chromatography (HPLC) as a separation technique (see L6.01).

02 Describe the principles of HPLC that apply to its use as an analytical tool.

03 Identify and characterize components of a high-performance liquid chromatograph.

04 Identify various column phases (normal, reverse, etc.) and describe the appropriate use of each.

05 Identify various detectors (e.g., diode array, ultraviolet [UV], mass spectrometry [MS]) used in HPLC instruments and choose the most appropriate for a variety of situations.

06 Identify parameters of a high-performance liquid chromatograph that influence the chromatogram.

Recommended Competencies

07 Install columns into HPLC instruments.

08 Calibrate one or more HPLC instruments (see L6.03).

09 Use HPLC to separate a known mixture; install columns, choose solvents, choose detectors, and perform calibrations; calculate the percentage of components in mixture.

10 Maximize the performance of an HPLC instrument by adjusting parameters to optimize peak width and resolution and minimize tailing.

11 Select the appropriate high-purity solvents for HPLC.

12 Operate a computer-controlled HPLC instrument.

Continued

13 Perform separations of unknown mixtures using HPLC.

14 Identify major vendors of HPLC equipment.

15 Provide examples of at least four uses of HPLC in local industry.

High-performance liquid chromatography (HPLC) is one of the most powerful and most frequently used analytical techniques for separating and identifying components of a mixture. HPLC is used commonly in the pharmaceutical industry. A technician, for example, was asked to analyze a new pharmaceutical product for stability, shelf life, and efficacy. The technician prepared the samples appropriately before conducting the analysis, knowing that for each analysis, different solvents and detectors would have to be used. Shelf-life analysis was especially sensitive, and the technician's understanding of HPLC principles ensured an accurate result. The report submitted by the technician was accepted by senior personnel, and the product was introduced to the Food and Drug Administration (FDA) for final approval.

L6.15

CHROMATOGRAPHY III—
THIN-LAYER CHROMATOGRAPHY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of thin-layer chromatography (TLC) as a separation tool (see L6.01).

02 Describe uses of TLC as an analytical tool.

03 Identify and describe components of the apparatus used to conduct TLC.

04 Identify and characterize effects of temperature, solvents, and plate types on conducting TLC separations.

Recommended Competencies

05 Conduct a TLC identification of a known mixture, including preparing and conditioning plates and/or spotting plates, performing the separation, scanning the plates, and interpreting the data.

06 Identify components in an unknown material using TLC.

07 Provide examples of at least three uses of TLC in industry.

Thin-layer chromatography (TLC), a technique used to separate a complex mixture of compounds, is commonly used by technicians to determine the stability of a given compound. For example, in the development of a new pesticide, a technician was studying the persistence and mobility of a pesticide in soil over time. The technician took soil samples from field test sites and stored them for an extended period of time. Using these samples, the technician used TLC to ensure there had been no degradation of the pesticide during storage. First, the pesticide was extracted from the soil with solvent. The technician then applied the concentrated extract to an aluminum plate coated with a thin layer of dried absorbent. The technician placed one end of the plate into a solvent, which triggered the separation. The solvent, pulled up by capillary action, ascended the plate and partitioned the moving liquid phase (the solvent) and the stationary solid phase (the absorbent). By comparing the results with a known standard, the technician determined that little or no degradation had occurred. This analysis assured the stability of the compound and the reliability of the results of the original studies.

X-RAY DIFFRACTION AND MICROSCOPY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of X-ray diffraction (see L6.01).

02 Identify analytical uses of X-ray diffraction.

03 Use a light microscope to examine samples; make observations regarding homogeneity/heterogeneity, size, color, and other physical characteristics.

04 Describe safety practices required for handling X-rays.

05 Describe regulations associated with X-ray analysis.

Recommended Competencies

06 Identify a variety of crystal types.

07 Describe the principle that provides the basis for the electron microscope.

08 Use the Bragg equation to calculate interplanar spacing.

09 Demonstrate how diffraction patterns are used in determining crystal structure.

10 Contrast diffraction and single-crystal X-ray analysis and describe situations in which each is applicable.

11 Use diffraction equipment to determine the structure of several known crystal types.

12 Identify the basic structure of an unknown sample using X-ray diffraction.

Continued

L6.16

13 Use (or observe the use of) an electron microscope to identify crystal structures.

14 Describe the difference among scanning electron microscopy (SEM), transmission electron microscopy (TEM), and scanning transmission electron microscopy (STEM); give examples of the use of each.

15 Provide examples of uses of X-ray and microscopic techniques in industry.

Powder X-ray diffraction techniques make use of the scattering of X-rays to identify and characterize crystalline compounds. For example, a cleanser manufacturer observed that product prepared with a new batch of mineral abrasive performed poorly. Samples of both old and new raw material were sent to the lab for identification and characterization. The laboratory technician assigned to the task used a diffractometer and obtained an initial pattern composed of both the positions and intensities of the diffracted X-rays. The pattern, which serves as a "fingerprint" of the material, indicated that there was a contaminant in the new material. Further investigation supported the technician's conclusions, and the problem was called to the attention of the vendor and the contaminant was removed.

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 180
COMPUTER 181
COMMUNICATION 182

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MATH & STATISTICS

Performing Instrumental Analysis	MODULES															
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
Read & Construct Graphs		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Calculate Ratios		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perform Unit Conversions		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perform Calculations Using Exponents					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perform Calculations Using Roots					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perform Calculations Using Logarithms								✓	✓	✓	✓	✓	✓	✓	✓	✓
Use Appropriate Significant Figures			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Recognize Patterns from Data		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Solve Single-Unknown Algebra Equations			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Solve Simultaneous Equations					✓			✓	✓		✓	✓		✓	✓	✓
Solve Quadratic Equations								✓	✓		✓			✓		✓
Calculate Means & Standard Deviations			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Calculate Accuracy & Precision of Data Sets			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Determine Control Limits			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Determine Detection Limits			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

COMPUTER

Performing Instrumental Analysis	MODULES															
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
Use a Computer Keyboard		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Access Database Information	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Develop & Maintain a Database		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use, Maintain & Develop Spreadsheets		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use Graphics Software			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use Microprocessors		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use Statistical Software			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Transfer Data to & from Remote Databases						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Conduct On-line Literature Searches	✓			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

COMMUNICATION

Performing Instrumental Analysis	MODULES															
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
Oral Communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Written Communication		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Read & Understand Procedures	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintain Log & Notes		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Keep Records		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Write Memos & Letters	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Write Technical Reports	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Give Clear, Concise Instructions		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Report Data	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintain Accurate Notebook	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Read & Prepare Diagrams	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Write Methods						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Conduct Literature Searches	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Read Technical Manuals & Journals	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

PLANNING, DESIGNING, AND CONDUCTING EXPERIMENTS

Introduction

The ability of chemical laboratory technicians (CLTs) to plan, organize, conduct experiments, and report results using a statistical approach is critical for work in research and development laboratories. The comprehensiveness and flexibility of the experimental program accentuates the difference between technicians working in control and technical service laboratories and those working in research and development laboratories.

Ensuring good experimental design provides an important link between scientists and technicians. In designing experiments, technicians are often expected to contribute their expertise as team members and play a key role in the planning, designing, conducting, and reporting of experiments. Experiments in this context can range in time from short, singular experiments to protracted experimental programs. All of the skills that technicians develop can be brought to bear when conducting experiments. The experiments incorporate testing, analysis, handling materials, safety/health and environmental (S/H/E) considerations, use of literature and references, communication, and mathematics/statistics skills. Laboratory experiments are the link between ideas and research products. When conducting experiments, laboratory technicians often make observations that are the basis for future experiments.

Technicians are often included in patents because of their technical contributions to the work. Upon completion of experiments, technicians often provide the link between the laboratory and the plant and participate in scale-up and technology transfer.

The modules developed for this Critical Job Function are presented according to the process used in planning and conducting experiments and provide students with knowledge of the process and necessary skills required. The technical skills used are cited elsewhere.

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TASKS

Tasks conducted by CLTs related to this Critical Job Function include:

- Working with team members to set goals and divide the work to be done.
- Conducting literature searches.
- Identifying resources (e.g., people, equipment, chemicals, and methods).
- Gathering chemicals and obtaining resources.
- Creating a statistical design for the experiment using a quality model.
- Designing control ranges as appropriate for the defined needs and the experimental conditions.
- Describing procedures in writing as appropriate for the intended audience.
- If appropriate, designing and running computer simulations.
- Performing experiments and procedures in the laboratory or field.
- Initializing and monitoring automated experiments.
- Evaluating and presenting results.
- Assessing and redesigning experiments as necessary.
- Reporting results.
- Working with team members to determine required follow-up activities.
- Implementing results, as appropriate.

TECHNICAL WORKPLACE STANDARDS

For this critical job function, entry-level CLTs are expected to:

- Plan and conduct experiments that utilize technical knowledge and skills developed as part of the specific duties used generally by laboratory technicians (e.g., analyzing materials, synthesis, separations, general laboratory skills, handling and sampling materials).
- Plan and conduct experiments involving both laboratory and field locations that include working as a member of a research team, conducting a literature search, designing experiments using appropriate statistical techniques, monitoring results over a period of time, and analyzing results.
- Develop and report conclusions or final results; document all phases of the work.

L7
Modules

01 **TOTAL QUALITY MANAGEMENT FOR THE TECHNICIAN** 187

02 **PLANNING EXPERIMENTS** 189

03 **DESIGNING EXPERIMENTS** 191

04 **CONDUCTING EXPERIMENTS** 193

05 **REPORTING RESULTS** 195

06 **WORKPLACE EXPERIENCE—PLANNING, DESIGNING, AND CONDUCTING EXPERIMENTS** 197

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L7.01

TOTAL QUALITY MANAGEMENT FOR THE TECHNICIAN

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe principles of total quality management (TQM).

02 Describe the role of the laboratory technician implementing TQM.

03 List and define steps involved in problem-solving procedures.

04 Draw a process diagram; identify input processes and outputs for an experiment conducted in the laboratory.

05 Describe elements of TQM as they relate to suppliers, procedures, and customers.

Recommended Competencies

06 Working with a team, construct a process flow diagram to describe a project or an experiment that is being conducted in the laboratory.

07 Identify ways to ensure that a process is under control.

08 Describe the concept of continuous improvement.

09 Use statistical tools such as fish bone (cause and effect) diagrams, Pareto charts, histograms, and scatter diagrams; demonstrate the use of each and describe the value of each in planning and designing experiments.

Technicians who maintain high standards in their work are able to perform assignments at high quality and low cost. Oftentimes, technicians who demonstrate excellence in the workplace are asked to collaborate with other employees in quality improvement teams. For example, a quality improvement team at a chemical manufacturing facility was asked to propose a way to minimize the cost of waste disposal. Using fish bone diagrams and Pareto charts, the team narrowed its choice to one feasible alternative: Burn the waste stream. An experienced technician agreed that this was a feasible alternative but suggested that because the waste stream was petroleum based, environmental regulations needed to be considered before implementation. Research of environmental regulations for waste stream disposal through incineration indicated that chromium levels could not exceed 10 ppm. The technician analyzed samples of the waste stream, determined that the chromium levels were below the regulatory threshold, and supported the team's decision to incinerate the waste.

L7.02

PLANNING EXPERIMENTS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the importance of "defining the problem" when conducting experiments.

02 Compare the role of the technician with that of other team members.

03 Compare the role of the scientist with that of other team members.

04 Describe how teams function, including the roles of different team members, and the value of diversity in teams.

05 Choose an experiment to be carried out; conduct a literature search and develop a report on previous work done pertinent to the experiment being carried out; and work as a member of a team in which each member has a role in planning an experiment by:

- identifying the goals
- assessing the available information
- assigning tasks for each of the team members
- developing a timetable
- monitoring results

Recommended Competencies

06 Identify areas of experimentation applicable to local employers; these areas might include experiments to measure stability, wear, similarity of a company's products to its competitors, and cause of off-spec materials.

For an experiment to be performed optimally, it should be planned carefully in advance. Planning includes conducting preliminary research, preparing samples, and setting up equipment. For example, a chemical process in an electronics manufacturing facility had become contaminated, and the chemical engineer needed to find the source of contamination. Lacking laboratory expertise, the engineer submitted a sample of the contaminated bath to the lab for analysis. After discussion with the engineer, the technician recognized that contamination could be a result of many factors, and testing for each one of the factors individually would be an unnecessarily lengthy and expensive process. To avoid unnecessary experimentation, the technician decided to conduct some preliminary research by studying chemical attributes, exploring the possible causes of contamination, and reviewing case studies of similar problems. After conducting this research, the technician decided that only two analyses were required to find the contamination source. When the technician conducted these experiments, the results were conclusive, and the contamination source was identified.

L7.03

DESIGNING EXPERIMENTS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Write a description of the principles of experimental design.

02 Develop plans for conducting an experiment.

03 Identify the critical steps in a procedure.

04 With team members, design an experiment based on L7.02.05 that will yield statistically valid results; determine the number of samples required for a valid experiment and the kind and quantity of data required to validate procedures.

Recommended Competencies

05 Estimate the error involved in each of the steps in a procedure.

06 Describe the concept of a "control experiment."

07 Discuss with engineers, scientists, and statisticians from local industry the approach they use when planning and designing experiments; explain how it differs from the experiments designed in L7.03.04.

Product development labs are regularly challenged with creating new products that do not infringe on existing patents nor cost extra money. One way to maximize efficiency is to design experiments carefully. For example, a customer ordered a low-cost matte finish from a printing and lithography firm. The lab technician knew that microparticles would give the proper finish, but the challenge lay in designing microparticles that would not infringe on patent rights of existing products. The technician planned the tests so that several particles were tested for several characteristics such as printing and gloss measurements. Furthermore, the technician designed an experiment using a nominal, intermediate, and maximum number of particles. The careful design of the experiment ensured that the product was useful to the customer.

L7.04

CONDUCTING EXPERIMENTS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Set up experiments based on the design established in L7.03.04.

02 Observe experiments in progress and record any observations in a laboratory notebook.

03 Construct charts and graphs representing the data obtained.

04 Relate the steps in a procedure to required tests and regulations.

05 Discuss results with team members on a regular basis, making suggestions for modifications.

06 Recognize the mechanical limitations of equipment being used.

07 Monitor work in progress.

Before pharmaceutical products can be approved by regulating agencies, they must be tested for shelf life. Such stability tests are carried out over several years and require consistent attention. Every six months, a technician must measure the active ingredients in a new drug to determine the recommended shelf life. When conducting analyses, the technician must make careful notes to ensure accurate records. The data will eventually be graphed to study trend analysis and establish shelf life. An error in recordkeeping may result in the assignment of an inaccurate shelf life—a mishap that consumers and manufacturers cannot afford.

REPORTING RESULTS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Calculate the precision and accuracy of experimental data.

02 Document results of the experiment in a written report, which includes:
- statement of the original problem
- results of the literature search
- experimental design
- results
- conclusions
- next steps

Recommended Competencies

03 Prepare an oral report regarding the experiment for presentation.

Reporting results is an imperative part of a technician's daily responsibilities. Accurate reports are essential as support documentation when a solution is being sought to a difficult problem. For example, a wastewater treatment plant had an influx of formaldehyde, which "killed" the biological processes. Plant technicians wanted to find the source of formaldehyde so that they could prevent future problems. The surrounding area included a few farms, a small town, a recently expanded campground, and some residential areas. None of the local industries used formaldehyde, nor was it a byproduct of their processes. A technician pulled samples from various locations throughout the sewer system and documented where the sample came from, the date and time pulled, and the conditions about the sampling area. After taking the sampling results to the lab and analyzing them, the technician concluded that the source of the formaldehyde was the recently expanded campground. With this information, the campground issued regulations to maintain formaldehyde levels and prevent this situation from happening again.

L7.06

WORKPLACE EXPERIENCE—PLANNING, DESIGNING, AND CONDUCTING EXPERIMENTS

To develop the necessary skills required to plan, design, and conduct experiments, it is important that the technician spend time in a laboratory and work as a team member with senior technicians and scientists in planning, designing, and conducting experiments.

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Work with scientists or senior technicians from local science technology employers to plan, design, carry out, and report on an experiment that covers all of the concepts included in modules L7.01–L7.04; the experiment should be of importance to the local employers and include all or most of the following critical steps:
- sampling
- testing
- performing mechanical operations
- separating or conditioning the sample
- performing analyses using chemical and instrumental methods
- taking data over a period of time
- recording results

02 Prepare a report that describes:
- the characteristics of the team and how the team worked
- the goals of the experiment
- the background information collected
- how the design was created
- the experimental design
- how the experiments were conducted
- the results
- the conclusions
- what was learned

Recommended Competencies

03 Prepare an oral presentation that describes the work performed.

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 200
COMPUTER 201
COMMUNICATION 202

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MATH & STATISTICS

Planning, Designing, and Conducting Experiments	MODULES					
	01	02	03	04	05	06
Read & Construct Graphs	✓		✓	✓	✓	✓
Calculate Ratios			✓			✓
Perform Unit Conversions			✓			✓
Perform Calculations Using Exponents			✓			✓
Use Appropriate Significant Figures	✓		✓	✓		✓
Recognize Patterns from Data	✓		✓	✓	✓	✓
Solve Single-Unknown Algebra Equations			✓			✓
Calculate Means & Standard Deviations	✓		✓	✓	✓	✓
Calculate Accuracy & Precision of Data Sets	✓		✓	✓	✓	✓
Determine Control Limits	✓		✓	✓	✓	✓
Determine Detection Limits	✓		✓	✓	✓	✓

COMPUTER

Planning, Designing, and Conducting Experiments	MODULES					
	01	02	03	04	05	06
Use a Computer Keyboard	✓	✓	✓	✓	✓	✓
Access Database Information	✓			✓	✓	✓
Develop & Maintain a Database		✓	✓	✓	✓	✓
Use, Maintain & Develop Spreadsheets	✓			✓		✓
Use Graphics Software	✓				✓	✓
Use Microprocessors	✓			✓	✓	✓
Use Statistical Software	✓	✓	✓	✓	✓	✓
Transfer Data to & from Remote Databases	✓		✓	✓	✓	✓
Conduct On-line Literature Searches	✓			✓		✓

COMMUNICATION

Planning, Designing, and Conducting Experiments	MODULES					
	01	02	03	04	05	06
Oral Communication	✓	✓	✓	✓	✓	✓
Written Communication	✓	✓	✓	✓	✓	✓
Read & Understand Procedures	✓	✓	✓	✓		✓
Maintain Log & Notes	✓		✓	✓		✓
Keep Records	✓		✓	✓		✓
Write Memos & Letters					✓	✓
Give Clear, Concise Instructions	✓	✓			✓	✓
Report Data	✓		✓	✓		✓
Maintain Accurate Notebook	✓	✓	✓	✓	✓	✓
Read & Prepare Diagrams	✓		✓	✓	✓	✓
Write Methods					✓	✓
Conduct Literature Searches	✓	✓	✓	✓	✓	✓
Read Technical Manuals & Journals		✓	✓	✓		✓

SYNTHESIZING COMPOUNDS

Introduction

Chemical laboratory technicians (CLTs) employed in research and development laboratories are likely to synthesize compounds. Knowledge of chemical principles and the best methodologies for conducting syntheses are critical to success. Because synthesizing compounds ties together several aspects of the work of a technician, it is important that the process of synthesis be conducted in conjunction with all other developed skills.

To ensure safe operations and high-quality synthesis, technicians are expected to demonstrate the following important skills: understanding chemical reactivity, using knowledge of chemical nomenclature effectively, using symbols accurately, writing and balancing equations, choosing and assembling glassware properly for a variety of reaction types, and understanding and conducting the essential aspects of monitoring reactions using analytical measurement tools. Because technicians work closely with scientists when engaged in synthesis, communication and team skills are also critical. In addition, technicians must be able to access literature effectively and report data and observations accurately according to company and patent law policy.

Scale-up, although generally not performed by technicians early in their careers, is an important aspect of the work done in a synthesis laboratory, and the educational program should reflect an awareness of this critical next step and the principles that affect it. Furthermore, because there are several subspecialties in the chemical processing industry (CPI), including pharmaceutical, polymer, inorganic, and other chemical manufacturing, educational programs must include local workplace experiences, which should be designed in conjunction with local alliances.

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TASKS

Tasks conducted by CLTs related to this Critical Job Function include:

- Familiarizing oneself with reaction characteristics before performing syntheses, including the nature of the reaction (kinetics, equilibrium, exothermic/endothermic, etc.).
- Determining all safety and handling aspects of the work to be conducted (e.g., consider side reactions).
- Identifying and obtaining information relevant to specific laboratory activities.
- Obtaining starting materials and solvents in appropriate quantities and conditions.
- Determining the purity of the starting materials, if appropriate.
- Obtaining and calibrating all the monitoring instruments required.
- Assembling necessary glassware, instruments, and equipment for a synthesis procedure.
- Establishing the proper starting conditions and setting the required instrument parameters as appropriate for the experiment to be conducted.
- Initiating the reaction.
- Monitoring the reaction.
- Collecting and purifying the product of the reaction (e.g., filter, evaporate, crystallize).
- Verifying the identity and characterizing the purity of the product, as appropriate.
- Analyzing product sample (or submitting for analysis) to determine the purity and for confirmation of structure.
- Disassembling, cleaning, and returning equipment, glassware, and other materials used to proper stored conditions.
- Documenting all findings in a laboratory notebook, obtaining witness signatures, and discussing results with team members.
- Participating in planning next steps.

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level CLTs are expected to:

- Apply information and concepts of applied general, organic, inorganic, and physical chemistry to synthesizing compounds.
- Classify organic and inorganic reactions in common groups and write chemical equations for and describe unique features of common types of chemical reactions.
- Write reactions involving various functional groups.
- Describe basic concepts of commercially important types of polymerization reactions.
- Apply concepts of chemical reactivity, kinetics, stoichiometry, and equilibrium to the conduct of chemical syntheses and analyses under common laboratory conditions.
- Balance chemical equations.
- Identify, use, and care for glassware and equipment associated with conducting chemical reactions.
- Purify reagents to be used in synthesis.
- Conduct reactions of different types for organic and inorganic materials at a variety of scales and under a variety of reaction conditions.
- Crystallize, evaporate, sublime, extract, and use phase separations and other purification and separation techniques for both organic and inorganic materials.
- Determine reaction yields using chemical stoichiometry.
- Calibrate on-line laboratory instruments.
- Use a variety of chemical and instrumental techniques to determine the structure of organic and inorganic materials.
- Conduct a literature search and use major synthesis references.
- Honor the concepts of intellectual property and patents and the role of technical personnel in implementing these concepts.
- Submit samples for the analyses required to calculate purity and yield.
- Understand chemical engineering principles in scaling up preparations.

L8
Modules

01 **INTRODUCTION TO ORGANIC SYNTHESIS . . . 207**
02 **CHEMICAL REACTIONS . . 209**
03 **POLYMERIZATION REACTIONS 211**
04 **LABORATORY PROCESSES 213**
05 **OBTAINING THE NECESSARY INFORMATION TO CONDUCT A SYNTHESIS 215**
06 **PREPARING TO CONDUCT A SYNTHESIS . 217**
07 **CONDUCTING A SYNTHESIS 219**
08 **MOLECULAR MODELING 221**
09 **PROTECTING INTELLECTUAL PROPERTY 223**
10 **SCALE-UP CHEMICAL REACTIONS 225**
11 **WORKPLACE EXPERIENCE— SYNTHESIZING COMPOUNDS 227**
12 **WORKPLACE EXPERIENCE— SCALE-UP 229**

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L8.01

INTRODUCTION TO ORGANIC SYNTHESIS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Define "synthesis" and give examples of several classical reactions; describe the process of synthesis for each.

02 Outline, in detail, steps for conducting a synthesis, including relationships between team members, particularly those between technicians and chemists.

03 Identify equipment appropriate for conducting syntheses, including small-scale and microscale syntheses.

04 Document common synthesis procedures for a variety of compounds of interest to local employers and identify the impact of each synthesis step on the overall production or experimental process.

05 Identify organic functional groups, including alcohols, aldehydes, ketones, and carboxylic acids, and describe the chemical characteristics of each.

Recommended Competencies

06 Describe chemical reactivity by writing and balancing reactions involving organic functional groups.

L8.02

CHEMICAL REACTIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify and write chemical equations that represent:
- nucleophilic reactions
- electrophilic reactions
- fermentation reactions
- polymerization reactions
- condensation reactions
- other reactions important to local needs/activities

02 Write and describe chemical reactions that involve functional groups, such as:
- carboxylic acids
- ketones
- aldehydes
- alcohols
- ethers
- other common organic and inorganic groups

03 Describe LeChatlier's principle and how it affects chemical reactions.

Recommended Competencies

04 Identify characteristics of chemical equilibrium and kinetics involved for each type of common chemical reaction and how rates of reaction affect chemical synthesis procedures.

05 Identify characteristics of the chemical thermodynamics involved for each type of common reaction and how thermodynamics affects the reaction.

L8.03

POLYMERIZATION REACTIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify reactions that are important in polymer chemistry.

02 Classify polymers according to types.

03 Identify common processes that are important in polymerization.

04 Identify commercial products that are polymers and write the chemical reactions used to produce them.

05 Identify principal rheological properties of polymers.

06 Determine formula weight of polymers.

07 Relate chain length to properties of polymers.

08 Perform several polymerization reactions.

It is important that a laboratory technician be familiar with polymerization reactions, because they are a common component of a laboratory technician's job. For example, a technician in a laboratory was asked to analyze cellophane for formaldehyde residue. The technician obtained samples, cut them up, extracted them with a solvent, and then analyzed them for formaldehyde by using a gas chromatograph. Results obtained using this test indicated unusually high levels of formaldehyde. After some research and investigation, the technician discovered that insufficient rinsing was the cause for the contamination. The technique for removing formaldehyde from cellophane was modified to ensure the purest quality.

L8.04

LABORATORY PROCESSES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the major processes used in the synthesis laboratory to separate and purify materials.

02 Using standard laboratory equipment, identify and set up the equipment and carry out experiments using the following:
- simple distillation
- steam distillation
- fractional distillation
- azeotropic distillation
- reflux extraction
- liquid/liquid extraction
- recrystallization
- evaporation
- filtration
- sublimation

Recommended Competencies

Maximizing the yield of chemicals in a laboratory is an essential goal when conducting a synthesis. Technicians, therefore, should be knowledgeable of different techniques and the appropriate conditions for each. For example, a laboratory technician was preparing an isocyanate that had to have lower molecular weight products removed by distillation. However, when each batch was stripped in a flask, the yields of the desired product were unsatisfactory. Unwanted side reactions were decreasing yields because of the long residence times in the flask at the required distillation temperature. The technician changed to a thin-layer evaporator to reduce the amount of time the reaction mixture was at the distillation temperature, and the yield and quality of the product were both improved.

L8.05

OBTAINING THE NECESSARY INFORMATION TO CONDUCT A SYNTHESIS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Locate and use pertinent chemical reference materials.

02 Obtain from a literature search all the appropriate background information required to conduct a specified synthesis.

03 Write a short paper based on a literature search pertinent to a specific reaction; include what has been done before, expected yields, and safety considerations for conducting reactions.

04 Search literature using electronic database technology to obtain abstracts and documents pertaining to the chemical synthesis to be conducted.

Recommended Competencies

05 Compile information obtained from the literature and design a synthesis procedure from it.

06 Make adaptations to accommodate available equipment when the equipment specified in a documented procedure is unavailable.

Synthesis can be a complex process; therefore, technicians must be thorough and thoughtful of each step in the procedure. For example, a technician was synthesizing polyamines, making the ethoxylation runs in a stirred autoclave. Several of the autoclave runs produced material with qualitatively correct nuclear magnetic resonance (NMR) spectra; however, the technician calculated that the degree of ethoxylation was at least 20% higher than expected based on the amount of ethylene oxide added. To be sure that the results were correct, the technician decided to confirm the findings via titration to measure acidity. The technician was able to determine the region over which the polyamine was being protonated, assess the equivalents per gram, and convert these results to the equivalent weight.

L8.06

PREPARING TO CONDUCT A SYNTHESIS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Calculate theoretical yield based on the stoichiometry of the reaction to be performed.

02 Select and assemble appropriate glassware and equipment required for a synthesis.

03 Obtain and purify the reagents necessary for a synthesis.

Recommended Competencies

04 Identify experimental procedures appropriate to exothermic and endothermic reactions.

When preparing to conduct a synthesis, potential exotherms, possible side reactions, and effects of impurities need to be considered. For example, a laboratory technician planned to conduct a synthesis that was known to have a high heat of reaction. Initially, the technician carried out the reaction in a small flask to gain experience in maintaining a constant reaction temperature. After testing several techniques, the technician found that the exotherm could be controlled best with the combination of a water bath and an air gun. Once confident that this technique was suitable on a small scale, the technician increased the size of the laboratory equipment incrementally. This technique was effective in maintaining the temperature in small and 1-liter flasks. It was at this point that the technician could conduct the synthesis at the desired quantity with confidence that possible side reactions would not occur.

L8.07

CONDUCTING A SYNTHESIS

Core Competencies

Upon completion of this module, the technician will be expected to:

01 Synthesize organic compounds involving chemical reactions and procedures that require special environments (dry box, vacuum, etc.) at standard and at micro scales.

02 Determine the purity of products using thin-layer chromatography (TLC), gas chromatography (GC), high-performance liquid chromatography (HPLC), and other instrumental techniques.

03 Purify synthesis products using recrystallization, distillation, extraction, filtration, etc.

04 Analyze synthesis products and compare actual with theoretical yield.

When conducting a synthesis, a technician should use correct procedures and be mindful of safety considerations. Careful, well-documented procedures will make it possible for the technician to conduct the synthesis accurately and safely. For example, a technician in a chemical laboratory was reacting an amine with phosgene to form an isocyanate. Because of phosgene's hazardous nature, the technician reviewed the safety checklist before the reaction was begun and followed the safety checklist and standard procedure during the reaction itself. Throughout the synthesis, the technician carefully took notes and kept records. After completing the reaction, the technician removed the solvent by vacuum distillation and analyzed the isocyanate product by gel permeation chromatography (GPC). The GPC technique confirmed that the product was pure, and the technician knew that the synthesis had been conducted safely.

L8.08

MOLECULAR MODELING

This module is intended for advanced students who plan to work in research and development laboratories and requires a working knowledge of concepts in organic chemistry, including:

- *a basic understanding of quantum theory as it applies to the structure of organic molecules*
- *familiarity with the structure of macromolecules*
- *familiarity with the three-dimensional nature of molecules*

Upon completion of this module, the technician will be expected to:

Recommended Competencies

01 Identify software specifically designed for molecular modeling.

02 Using molecular modeling software, create and manipulate several common molecular structures, calculate charges, print in a graphical format, and prepare a spreadsheet.

03 Calculate energy confirmations from structural information.

04 Correlate statistical output with activity using quantitative structure–activity relationships (QSAR).

05 From molecular components, sketch out potential three-dimensional designs and relate to chemical activity.

Molecular modeling is used to understand and visualize structural properties of existing compounds and to predict properties and activities of new chemical entities. It is therefore important that chemical laboratory technicians have an understanding of basic molecular modeling principles. Developments in computer hardware and software technology have enabled technicians to better understand molecular modeling activities.

L8.09

PROTECTING INTELLECTUAL PROPERTY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Present an overview of the law regarding the protection of intellectual property as applicable to work done in the chemical laboratory.

02 Identify characteristics required for notebooks to meet legal requirements.

03 Identify respective responsibilities in the patent process for the principal investigator (scientist), technician, witness, and attorney.

Recommended Competencies

04 Search patent literature and identify characteristics of the information available.

05 Identify a few important patent cases that have affected the chemical industry.

06 Identify components of an inventions memo.

Intellectual property is a very sensitive topic for manufacturers and researchers alike. Technicians have a responsibility to maintain accurate records and notebooks to protect intellectual property rights. For example, two major firms had developed an identical new product within weeks of each other. The company that developed the new product first submitted the patent application later than the second company. Laboratory notebooks and records were retrieved to prove which company had developed the product first. The technician representing the first company had a very accurate and detailed notebook, including dates, tasks, results, and work plans. The technician's notebook was enough evidence to convince the patent panel that the company had indeed developed the product first, and the intellectual property rights were transferred back to the rightful company.

L8.10

SCALE-UP CHEMICAL REACTIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe issues associated with moving from procedures at a laboratory scale to pilot plant, and from pilot plant to commercial plant scale, including the effects of kinetics, equilibrium, yields, and waste streams.

Recommended Competencies

02 Use models to predict results when scaling up laboratory procedures.

03 Visit local pilot plants and commercial plants and observe the processes being used for scale-up.

Scaling up to larger equipment can affect yields, exotherms, quality, and wastes. It is important for laboratory technicians to understand that a reaction conducted on a small scale could be very different than a reaction on a large scale. For example, a technician conducted several runs of a reaction in a laboratory. The computer data acquisition and control system indicated a small, easily controllable exotherm in the laboratory equipment. The technician knew that in a scaled-up reaction, the surface area to volume ratio would be lower than that of the laboratory run. Moreover, the technician understood that when the ratio was low, the temperature would be too high for a proper reaction. Further calculations confirmed this understanding, and the technician arranged for additional cooling of equipment for this reaction, avoiding the potential for an uncontrollable exotherm in the plant-size equipment.

L8.11

WORKPLACE EXPERIENCE—SYNTHESIZING COMPOUNDS

To develop the necessary skills to carry out syntheses, it is important that the technician spend time observing and working in a laboratory where syntheses are conducted.

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Work as a team member with an industry group.

02 Perform the required steps as defined by an industrial chemist to prepare for conducting syntheses, assemble the equipment, start and monitor the reaction, measure and purify the product, and calculate the yield.

03 Prepare a report that describes the chemical reactions, literature research, processes used to perform the synthesis, and results.

L8.12

WORKPLACE EXPERIENCE — SCALE-UP

To develop the necessary skills to perform syntheses, it is important that the technician spend time observing and working in a laboratory where scale-up is performed.

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify equipment used in a pilot plant.

02 Participate in assembling equipment for scale-up of a chemical reaction.

03 Relate information and process used in a laboratory-scale synthesis to a scaled-up version.

04 Provide support to the chemist, chemical engineer, and senior technician in scaling up reactions.

05 Prepare a report on the experience that notes the differences between the laboratory-scale and the scaled-up version of the reaction; include yield, intermediate products, and purity.

L8

MATH & STATISTICS 232
COMPUTER 233
COMMUNICATION 234

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS

Synthesizing Compounds	MODULES											
	01	02	03	04	05	06	07	08	09	10	11	12
Read & Construct Graphs			✓				✓	✓		✓	✓	✓
Calculate Ratios			✓	✓				✓		✓	✓	✓
Perform Unit Conversions		✓	✓	✓		✓	✓			✓	✓	✓
Perform Calculations Using Exponents		✓	✓			✓	✓			✓	✓	✓
Perform Calculations Using Roots		✓					✓			✓	✓	✓
Perform Calculations Using Logarithms		✓					✓			✓	✓	✓
Use Appropriate Significant Figures		✓	✓	✓		✓	✓				✓	✓
Recognize Patterns from Data					✓		✓	✓	✓	✓	✓	✓
Solve Single-Unknown Algebra Equations		✓	✓			✓	✓			✓	✓	✓
Solve Simultaneous Equations		✓					✓			✓	✓	✓
Solve Quadratic Equations		✓									✓	✓
Calculate Means & Standard Deviations			✓				✓				✓	✓
Calculate Accuracy & Precision of Data Sets			✓					✓			✓	✓
Determine Control Limits											✓	✓
Determine Detection Limits											✓	✓

COMPUTER

Synthesizing Compounds	MODULES											
	01	02	03	04	05	06	07	08	09	10	11	12
Use a Computer Keyboard	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Access Database Information	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Develop & Maintain a Database					✓	✓	✓	✓	✓	✓	✓	✓
Use, Maintain & Develop Spreadsheets						✓					✓	✓
Use Graphics Software								✓			✓	✓
Use Microprocessors	✓		✓		✓			✓			✓	✓
Use Statistical Software			✓					✓			✓	✓
Transfer Data to & from Remote Databases								✓	✓	✓	✓	✓
Conduct On-line Literature Searches	✓				✓			✓	✓		✓	✓
Use Process Modeling Software							✓	✓	✓			✓

L8

COMMUNICATION

Synthesizing Compounds	MODULES											
	01	02	03	04	05	06	07	08	09	10	11	12
Oral Communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Written Communication	✓				✓	✓	✓	✓	✓	✓	✓	✓
Read & Understand Procedures	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintain Log & Notes	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Keep Records								✓		✓	✓	
Write Memos & Letters			✓			✓	✓	✓	✓	✓	✓	
Write Technical Reports			✓			✓	✓	✓			✓	
Give Clear, Concise Instructions								✓			✓	
Report Data								✓	✓	✓	✓	
Maintain Accurate Notebook					✓	✓	✓	✓	✓	✓	✓	
Read & Prepare Diagrams					✓	✓	✓	✓	✓	✓	✓	
Write Methods			✓					✓			✓	
Conduct Literature Searches			✓		✓	✓	✓	✓	✓	✓	✓	
Read Technical Manuals & Journals	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	

The Critical Job Functions for process technicians (PTs) are:

P1: Working in the Chemical Process Industries

P2: Maintaining Safety/Health and Environmental Standards in the Plant

P3: Handling, Storing, and Transporting Chemical Materials

P4: Operating, Monitoring, and Controlling Continuous and Batch Processes

P5: Providing Routine and Preventive Maintenance and Service to Processes, Equipment, and Instrumentation

P6: Analyzing Plant Materials

The learning strategies for PTs were developed by the following team of contributors:

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WORKING IN THE CHEMICAL PROCESS INDUSTRIES

Introduction

The chemical process industries (CPI) are a major part of U.S. business and represent a large diversity of industries ranging from pharmaceuticals to large-scale processing of gasoline and plastics. Every product that we handle each day has had some origin in the CPI. Working in the CPI represents a particular challenge with regard to handling materials. Materials range from small quantities of specialized products to large quantities of potentially hazardous materials. Process technicians (PTs) or operators, as they are sometimes called, team with engineers and other technicians with specialties such as instrumentation, electronics, or maintenance to adjust and optimize conditions for the production of large quantities of products. The quality of the products produced is dependent on the skill and knowledge of the PT in carrying out the operations of the plant. PTs must be concerned with issues involved in personal and co-worker safety, impact of materials on the environment, and process skills that deal with all aspects of controlling processes and maintaining and caring for equipment. Knowing about the CPI is an important step in the overall process of becoming a PT.

The modules developed for "Working in the Chemical Process Industries" provide the PT with the knowledge and skills required to understand the business and effectively contribute at the workplace.

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P1
Modules

01 INTRODUCTION TO THE CHEMICAL PROCESS INDUSTRIES 241

02 EMPLOYMENT IN THE CHEMICAL PROCESS INDUSTRIES 243

03 QUALITY IN THE CHEMICAL PROCESS INDUSTRIES . . 245

04 WORKPLACE SKILLS NECESSARY FOR SUCCESS IN THE CHEMICAL PROCESS INDUSTRIES 247

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P1.01

INTRODUCTION TO THE CHEMICAL PROCESS INDUSTRIES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the chemical process industries (CPI) in relation to overall industry in the United States with regard to capital investment, percentage gross national product (GNP), and number of employees.

02 List major industries that are part of the CPI and the major products associated with each.

03 Identify major raw materials used in the manufacture of chemicals.

04 Describe how the CPI affect the average citizen.

05 Describe how the CPI contribute to the improvement of the standard of living.

06 Identify major components of a chemical company and describe how they are all interrelated (include research, development, processing, manufacturing, marketing, and sales).

07 Discuss current issues associated with the CPI such as global competition, the increase in regulations pertaining to safety and environment, technology advancement in chemistry, new models for chemical operations (by technology vs. internal research), and ways in which the industry is responding.

P1.02

EMPLOYMENT IN THE CHEMICAL PROCESS INDUSTRIES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify careers and career paths within the chemical process industries (CPI); note how the process technician (PT) fits into the overall scheme.

02 Discuss current trends in the way PTs are employed in the local industry by comparing members who work directly in the industry (hired by company) vs. those who work indirectly (contractors).

03 Discuss the educational preparation required for a variety of jobs, including PT, laboratory technician, engineer, chemist, maintenance worker, and instrument technician.

04 Meet with PTs working in local industry and discuss the kind of work done and ways they have contributed to the business.

05 Describe actions that must be taken by PTs to keep current in an ever-changing environment.

06 Identify operations in the local area in which PTs are represented by a union and those in which they are not; discuss the differences.

Careers in the chemical industry can take many different directions and provide unlimited opportunities to anyone willing to build on his or her experience and interests. Entry-level jobs serve as a solid foundation from which individuals can better establish these interests and talents and build a rewarding career. For example, an individual's career began in an ethylene unit of a large chemical company. The work was highly technical and changed frequently based on the different research projects that were pursued. After several years, the individual accepted a promotion into the waste water treatment unit. This unit was very different from the ethylene unit and offered many new challenges. The individual was able to utilize past technical experience for making important decisions quickly, which the waste water unit demanded. The individual's value was enhanced through continued education under the company education assistance plan. After several years of demonstrating proficiency in the work inside and outside the company, the employee accepted a position in the marketing department of the corporate headquarters. Prior experience in technical and production aspects of the products was invaluable. Customers valued this expertise and, consequently, the employee was able to successfully market the product and have a very positive impact on the company.

P1.03

QUALITY IN THE CHEMICAL PROCESS INDUSTRIES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe principles of total quality management (TQM).

02 Describe the role of the process technician in implementing TQM.

03 List and define steps involved in problem-solving procedures.

04 Describe elements of TQM as they relate to suppliers, producers, and customers.

05 Draw a process diagram for a chemical operation; identify inputs, process, and outputs.

06 Describe the concept of "continuous improvement."

07 Working with a team, construct a process flow diagram to describe an industrial process or a project or an experiment that is being conducted in the school laboratory.

Recommended Competencies

08 Working as part of a team, for a chemical operation, identify those TQM procedures, elements, and principles that contribute to defect prevention.

09 Determine conformance specifications by comparison of inspection done with product specification.

10 Use statistical tools such as fish bone (cause and effect) diagrams, Pareto charts, histograms, and scatter diagrams; demonstrate the use of each and describe the value of each in planning and designing experiments.

P1.04

WORKPLACE SKILLS NECESSARY FOR SUCCESS IN THE CHEMICAL PROCESS INDUSTRIES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Understand the importance of teamwork and have experience working as a member of a team for planning, performing, analyzing, and reporting.

02 Recognize that all members of a team have opinions that must be valued.

03 Demonstrate skills in problem solving.

04 Demonstrate responsibility for fellow workers' health and safety.

05 Demonstrate critical thinking.

06 Successfully coordinate several tasks simultaneously.

07 Make decisions based on data and observations.

08 Pay close attention to details and observe trends.

09 Demonstrate high ethical standards in all aspects of work.

10 Apply total quality management (TQM) principles to all aspects of work.

MAINTAINING SAFETY/HEALTH AND ENVIRONMENTAL STANDARDS IN THE PLANT

Introduction

Safety/health and environmental (S/H/E) protection must be a continuous, high-level concern to every technical worker in the chemical processing industry (CPI). Process technicians (PTs) working in this industry may handle hazardous materials and operate potentially dangerous equipment as a major part of their work. Improper handling can have serious effects on the environment, other individuals, the PT, and the physical facility. PTs must be aware that maintaining S/H/E standards is the most important part of their work. Regulations specific to the CPI have been developed at the federal, state, and local governmental levels. In addition, industry groups and individual companies have developed procedures to ensure the safety and health of employees, consumers, and the environment.

Regulations require continuous monitoring and extensive record keeping that address the environmental impact of chemicals, the processes used to make them, and their storage and disposal. PTs are the employees who have the most direct contact with, and control of, the chemicals and related products. They must accept responsibility for ensuring that S/H/E considerations are addressed appropriately.

PTs must be able to implement the regulations pertaining to the industry and to the processes in which they work. Knowing the regulations is not sufficient—the PT also must understand the reasons for them and the consequences of not adhering to them. Further, PTs must have significant knowledge about the materials they handle and the processes they operate.

The modules developed for this Critical Job Function are designed to prepare students to become PTs having knowledge of regulations, tools to deal with safety issues in the plant, and skills to respond correctly and promptly to conditions affecting personal and co-worker safety and environmental protection.

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TASKS

Tasks conducted by PTs related to this Critical Job Function include:

- Accessing procedures, files, and other documentation for S/H/E guidelines before starting any job and responding appropriately.
- Inspecting all areas for hazards.
- Providing input to co-workers about unsafe conditions.
- Complying with procedures for red tag lockout; handling all chemicals safely; and correctly implementing confined-space entry procedures.
- Investigating accidents and incidents as part of process safety management.
- Working closely with safety and regulatory contacts; participating in S/H/E audits.
- Reporting any conditions of concern that may affect the safety or health of self or co-workers or that could have an impact on the environment.
- Properly labeling all materials in the plant.
- Participating in public awareness activities.
- Participating in and conducting safety response drills.
- Verifying the completeness of appropriate paperwork.
- Participating in audits and safety reviews.

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level PTs are expected to:

- Describe federal, state, and local regulations that apply to the production or processing of petroleum, chemicals, and other chemical material.
- Describe federal, state, and local regulations and know how they apply to the part of the chemical industry in which they are used.
- Describe how federal, state, and local regulations directly affect the work of PTs and chemical laboratory technicians.
- Describe typical employer procedures for addressing regulatory issues; on starting work, examine and implement procedures that satisfy safety and regulatory requirements.
- Participate in developing an emergency safety plan.
- Be aware of "Right to Know" legislation and how it applies to plant environments.
- Be aware of emergency response procedures for marine environments as well as for land.
- Identify chemicals by their common and chemical names and by their chemical formulas.
- Classify compounds into common categories and describe safety and toxicity characteristics of each major class.
- Identify, determine the condition of, and properly use all major equipment associated with plant safety, including personal protective equipment (PPE), fire extinguishers, fire blankets, and Scott air packs.
- Use and maintain a radio for communication.
- Use approved first aid techniques for injuries to workers and describe corporate policy regarding such treatment.
- Care for a person who becomes incapacitated until official help arrives.
- Use monitoring equipment to measure air and water quality to ensure environmental compliance.
- Describe possible chemical reactions, heats of reactions, and kinetics associated with materials being used or handled.
- Know how to use respirators.
- Assist in the development of standard operating procedures for new or modified procedures.
- Maintain PPE.
- Monitor unit area for leaks and spills at all times.

01 OVERVIEW OF THE IMPACT OF FEDERAL, STATE, LOCAL, AND COMPANY REGULATIONS AND POLICIES ON THE SAFETY/HEALTH AND ENVIRONMENTAL CONCERNS OF THE COMMUNITY, WORKER, AND CONSUMER 253
02 THE PROCESS TECHNICIAN'S ROLE IN MAINTAINING A SAFE AND HEALTHY PLANT ENVIRONMENT 255
03 PERSONAL AND CO-WORKER SAFETY 257
04 FIRE SAFETY 259
05 DEVELOPING AND EXECUTING AN EMERGENCY SAFETY PLAN 261

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P2.01

OVERVIEW OF THE IMPACT OF FEDERAL, STATE, LOCAL, AND COMPANY REGULATIONS AND POLICIES ON THE SAFETY/HEALTH AND ENVIRONMENTAL CONCERNS OF THE COMMUNITY, WORKER, AND CONSUMER

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify and describe the agencies (federal, state, and local) that develop and enforce regulations pertaining to the chemical and related industries and their area of responsibility.

02 Describe the specific worker and employer responsibilities required by the major safety/health and environmental (S/H/E) regulations, including but not limited to:
  - Environmental Protection Agency (EPA) Clean Air and Water Acts of 1990
  - Occupational Safety and Health Administration (OSHA) 1910.119, Process Safety Management
  - OSHA 1910.120, Hazardous Waste Operations and Emergency Response (HAZWOPER)
  - OSHA 1910.132, Personal Protective Equipment (PPE)
  - OSHA 1910.1200, Hazard Communication (HAZCOM)
  - Department of Transportation (DOT) 49.173.1, Hazardous Materials—General Requirements for Shipments and Packaging
  - EPA 40.264.16—*Code of Federal Regulations* (40 CFR 260–299)
  - Resource Conservation and Recovery Act (RCRA)
  - Risk Management Regulation

03 Categorize regulations according to their impact on:
  - air, water, solid waste, and/or noise
  - worker health and/or safety
  - consumer protection

04 Describe the safety and health impact on the worker as compliance with S/H/E regulations is achieved and maintained.

05 Describe the impact on the environment as compliance with S/H/E regulations is achieved and maintained.

Continued

06 Describe the regulations that affect local industry and their impact (economic, health, and environmental) on the consumer.

07 Discuss requirements for training of process technicians as outlined in OSHA 1910.119.

08 Identify two or more industry-specific changes in your geographical area prompted by S/H/E regulations.

09 List and describe the available methods, and the laws that provide them, that allow the citizens of a community to learn more about the chemicals and materials handled within a local industry; include "Right to Know."

Recommended Competencies

10 Visit a local industry site and describe what actions have been taken by management to improve worker safety and health and to minimize negative impact on the environment.

11 Describe to community members who are nonchemical workers how chemical process industry (CPI) employers and their employees work to be responsible citizens with regard to S/H/E issues.

12 Discuss the financial impact on the industry as it strives to achieve and maintain compliance with existing and pending S/H/E regulations.

P2.02

THE PROCESS TECHNICIAN'S ROLE IN MAINTAINING A SAFE AND HEALTHY PLANT ENVIRONMENT

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Using Occupational Safety and Health Administration (OSHA) 1910.119, Process Safety Management, as a representative regulation, describe the process technician's (PT's) responsibility in implementing safety/health and environmental (S/H/E) regulations.

02 List the information that a PT can secure from the manufacturer or distributor about their chemicals under "Right to Know" legislation.

03 Describe the application and intent of different tags and labels used in the identification and marking of hazardous materials used in the industry; use Department of Transportation (DOT) 173.1 as a reference.

04 Understand all labels and tags as well as conventions and symbols used.

05 Given the type, quantity, and exposure potential of a given hazardous material and the applicable material safety data sheet (MSDS), identify the appropriate personal protective equipment (PPE) to be used; be able to access MSDSs electronically.

06 Identify types of resources designed to provide S/H/E information for the operation of a given facility (e.g., standard operating procedures [SOPs], plant safety manuals [PSMs], vendor manuals) and their typical location within a chemical complex.

07 Identify and describe the intent of the necessary components of an SOP, including purpose, PPE required, consequences of deviation, condition statements before executing the procedure, and statements describing conditions following the procedure.

08 Use and maintain hand-held radios for communication.

09 Correctly perform basic electricity grounding and bonding procedures and use appropriate safety precautions for other electrical safety issues.

Continued

10 Demonstrate the ability to isolate an operating pump, using appropriate lockout/tag-out procedures.

11 Describe the intent of "zero energy" and the methods used to achieve it; include liquid draining, nitrogen purging, steaming, etc.

12 Describe isolation methods used to maintain "zero energy" conditions once achieved, such as blinding, disconnecting, and double-block bleeding.

13 Use several different air and water monitoring systems available such as Drager, Gasteck, and MSA O_2 analyzers to determine the existence and degree of toxic contaminants in a work environment.

Recommended Competencies

14 Critique an SOP for the techniques and methods used to describe and explain S/H/E issues.

15 Correctly follow safe operating procedures in start-up, shutdown, and preparation of process equipment.

16 Use written operating procedures for equipment; use safe procedures during installation, start-up, normal operations, and shutdown operations.

17 Participate in a hazard/operability (HAZOP) review of a process or a proposed change to a process.

Regulations are issued by local, state, and federal agencies as well as companies themselves. Plants that operate safely and optimally reflect the contributions of process technicians, who implement all levels of regulations. For example, a technician was asked to isolate a pump so that the maintenance team could perform repairs. The technician implemented lockout/ tag-out procedures as specified by state regulations. Implementing lockout/tag-out procedures correctly is important to the safety of the technician, maintenance personnel, and electricians who will work on the pump at later stages. Following company regulations, the technician closed each valve (intake and output) in a particular sequence. After closing each valve securely, the technician placed a labeled tag on it and recorded the tag identification in a logbook. Company regulations further required that a second technician double-check all valves and notebook entries before contacting maintenance personnel. A second technician reviewed and approved the technician's work. Only after all of these steps had been conducted did the operator turn the pump over to the maintenance team.

PERSONAL AND CO-WORKER SAFETY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Select and use appropriate personal protective equipment (PPE) for a variety of situations while working in the plant, including but not limited to, handling toxic/corrosive materials, biological materials, flammable materials, and materials with high vapor pressure.

02 Select and demonstrate the correct use of PPE for skin and general body protection such as acid suits, general slicker suits, chemical aprons, gloves, and boots.

03 Select and demonstrate the correct use of PPE for hearing protection such as earplugs and earmuffs.

04 Select and demonstrate the correct use of PPE for eye protection such as cover goggles, eyeglasses with side shields, and face shields (full and half).

05 Select and demonstrate the correct use of PPE for respiratory protection such as air supply (self-contained breathing apparatus [SCBA], hose line systems, and emergency escape packs) and air purification (full and half mask with acid gas, particulate, and hydrocarbon cartridges).

06 Demonstrate proper use of safety and health response equipment such as eye bubblers, safety showers, and fire blankets.

07 Demonstrate proper lifting techniques to prevent injury.

08 Demonstrate proper selection and use of firefighting and suppressant equipment such as fire extinguishers type A, B, C, and D (mounted, cart, and hand-held halon, carbon dioxide, and powder), deluge systems, fire turrets, and nozzle operations.

09 Use standard-issue operator hand tools, valve wrench, channel locks, adjustable wrench, pipe wrench, and others that may be identified when performing the different types of operator work according to procedures.

Continued

10 Demonstrate techniques used in performing basic first aid including CPR.

11 Recognize and follow on-site emergency response procedures and maps provided to safely guide the actions of employees in an emergency situation.

12 With a fellow student, demonstrate the responsibilities of a worker and co-worker when working in confined spaces.

13 Demonstrate the use of ropes and radios when working in confined spaces or other isolated locations within a plant.

14 Identify typical resources available for response to personal injury such as emergency medical technician, paramedic, and medical department.

Recommended Competencies

15 Describe the environmental conditions (fire triangle) required to support combustion.

16 Describe aspects of an ergonomically correct work site to protect against injury from repetitious actions, poor chair siting, and muscle strain.

17 Following a visit to a workplace, list tools and resources seen that support a safe work environment.

Safety cannot be overemphasized in any aspect of a process technician's job. As a matter of fact, in particularly hazardous situations, technicians will often work in pairs or small teams to ensure a safe working environment. For example, a vessel containing residual hydrocarbon was cleaned by being purged first with nitrogen, then with air. A process technician was then asked to crawl through a duct in the vessel and thoroughly clean the inside. Occasionally, pockets of nitrogen remain inside the vessel and pose a hazard to the technician performing the cleaning. A technician could even lose consciousness due to a lack of oxygen. The technician, aware of the dangers of this assignment, followed confined-space entry procedures, which required, among other things, that a second technician be outside the vessel in case of an emergency. Additionally, both workers were required to use ropes, radios, and respirators. As a result of the technician's adherence to confined-space entry procedures, the tank was cleaned properly and safely.

P2.04

FIRE SAFETY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the characteristics of fires that occur in chemical plant environments, including electrical, hydrocarbon, wood/paper, and chemical fires.

02 Describe the components required to support a fire.

03 Define the term "flash point" and explain the importance of knowing the flash point of a specific hydrocarbon.

04 Describe the difference between flash point and auto ignition.

05 Define the terms "upper and lower explosives limits" and explain the importance of knowing the actual values in a potentially hazardous situation.

06 Describe fire potential information in a material safety data sheet (MSDS).

07 Explain the importance of reporting even small fires that can be extinguished quickly.

08 Identify and describe the purpose of ChemTrec and the service it provides.

09 Identify the different types of firefighting vehicles used in the chemical industry (e.g., foam trucks, ladder trucks, hose trailers).

10 Describe the selection and application of the following fire extinguishers:
- foam
- dry powder
- dry chemical
- water
- nitrogen
- carbon dioxide
- halon

11 Describe the selection and application of hand-held fire extinguishers available for use in the chemical industry.

Continued

12 Select the correct firefighting equipment to use based on the type, size, and conditions of a fire.

13 Describe the operating procedures for each type of equipment from selection and use to recharge or discard.

14 Describe when control is a better option than extinguishing a fire.

15 Identify fire alarms in a specific industry plant and describe the action you would take in response.

16 Describe the importance of containment walls, deluge systems, explosive vapor monitoring systems, and pressurized work areas and the concept behind Safe Haven.

17 Describe how Mutual Aid agreements with other local entities, both industrial and municipal, work.

Understanding chemical fires is critical to the safety of a chemical operation. Because of the specific nature of different fires, process technicians must have a broad knowledge of different types of fires and different ways of defeating them. For example, at a chemical plant, a 55-gallon drum containing sludge oil and gasoline flush material was placed on a concrete pad next to the loading dock. A truck backing into the loading dock knocked over the barrel. Vapors from the spilled contents ignited, and the fire spread quickly, creating large flames and heavy smoke. Of the two technicians on the scene, one immediately sounded the alarm and called the fire crew. The second technician applied powder to the fire, knowing that water would not extinguish it, but would, in fact, spread it. Although the technicians could not stop the fire, their quick actions contained it long enough for the fire crew to arrive and extinguish it.

P2.05

DEVELOPING AND EXECUTING AN EMERGENCY SAFETY PLAN

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify and describe components of a safety plan for emergencies, including fire, spills/gas release, bomb threats, and inclement weather.

02 Identify and describe components of an Emergency Response Plan as per Occupational Safety and Health Administration (OSHA) 1910.120, Hazardous Waste Operations and Emergency Response (HAZWOPER); 1910.38, Employee Emergency Action Plans; and Fire Prevention.

03 Participate in a simulated emergency, both as a leader and as a victim.

04 Participate in an evacuation procedure.

05 Develop a safety awareness session for fellow students.

06 Audit a local Emergency Response Plan and check for the necessary components of the proper plan.

Recommended Competencies

07 Use a building plan of an existing facility with an on-site water treatment system using chlorine cylinders to develop an evacuation and response plan addressing a leaking cylinder evolution.

08 Use a trainee-developed review team to conduct a safety review and audit of the school laboratory and pilot plant and extend that work by identifying regulations that apply to full-scale plants that handle specified materials; identify areas of non-compliance and develop a plan for working with the staff to correct the items according to a timetable that addresses regulatory constraints; and report findings to the class.

In the event of an emergency, senior managers rely on process technicians to make sure that the safety plan is executed properly. For example, two contract workers hired for a short-term assignment had not signed in with the foreman at the beginning of their shift. Later in the day, a tank car ruptured, making it necessary to evacuate a three-block area of the plant. The two contract workers were working in an isolated area of the block and were unaware of the emergency procedures. Furthermore, because the contract workers hadn't signed in at the beginning of their shift, senior technicians would not have known that they were missing when doing headcounts. In accordance with the emergency shutdown and evacuation plans, a technician was making sure that the workplace was evacuated, found the two workers, and led them to safety.

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 264
COMPUTER 265
COMMUNICATION 266

MATH & STATISTICS

Maintaining Safety/ Health and Environmental Standards in the Plant	MODULES				
	01	02	03	04	05
Read & Construct Graphs		✓	✓		✓
Calculate Ratios		✓			✓
Perform Unit Conversions		✓			✓
Recognize Patterns from Data		✓			
Solve Single-Unknown Algebra Equations		✓			
Calculate Accuracy & Precision of Data Sets		✓	✓		
Determine Control Limits					✓
Determine Detection Limits		✓	✓		✓

COMPUTER

Maintaining Safety/ Health and Environmental Standards in the Plant	MODULES				
	01	02	03	04	05
Use a Computer Keyboard	✓	✓	✓		✓
Access Database Information	✓	✓	✓		✓
Develop & Maintain a Database	✓	✓			✓
Use, Maintain & Develop Spreadsheets			✓		
Conduct On-line Literature Searches	✓	✓	✓		

COMMUNICATION

Maintaining Safety/ Health and Environmental Standards in the Plant	MODULES				
	01	02	03	04	05
Oral Communication	✓	✓	✓	✓	✓
Written Communication	✓	✓	✓		✓
Read & Understand Procedures	✓	✓	✓		✓
Maintain Log & Notes		✓	✓	✓	✓
Keep Records	✓	✓	✓	✓	✓
Write Memos & Letters		✓	✓	✓	✓
Give Clear, Concise Instructions		✓	✓	✓	✓
Report Data		✓	✓	✓	
Maintain Accurate Notebook	✓	✓	✓	✓	✓
Read & Prepare Diagrams	✓	✓	✓		✓
Conduct Literature Searches	✓	✓			
Read Technical Manuals & Journals	✓				✓

HANDLING, STORING, AND TRANSPORTING CHEMICAL MATERIALS

Introduction

Process technicians (PTs) working in the chemical processing industry (CPI) are expected to handle, store, and transport chemical materials within the plant and are expected to arrange for transportation to and from the plant. To perform these jobs effectively and safely, PTs must be familiar with chemical and physical properties of the materials they handle and with issues and regulations associated with storing and handling the materials.

Many chemicals in the workplace are considered hazardous materials and must be handled with respect, requiring knowledge and understanding of properties of the materials. The physical and chemical characteristics of the material being stored must be compatible with specifications for storage containers and vessels ranging from laboratory glassware to tank storage facilities.

The modules developed for this Critical Job Function address issues affecting handling, storing, and transporting chemical materials, including the knowledge of chemistry to relate chemical and physical properties of types of materials, types of vessels, and containers used for storing materials, as well as issues related to transporting materials. Although marine terminal activities are mentioned, no attempt has been made to create a module sufficiently detailed for PTs working in this field.

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TASKS

Tasks conducted by PTs related to this Critical Job Function include:

- Receiving, verifying, and identifying materials and products from ships, trucks, railroads, and other carriers.
- Completing the proper paperwork associated with receiving materials.
- Unloading, or arranging for someone to unload, materials and products from ships, trucks, railroads, and other carriers.
- Transferring, or arranging to transfer, materials to storage or processing units.
- Properly labeling all materials.
- Ensuring that materials meet specifications by measuring specified properties.
- Maintaining material inventories.
- Maintaining storage facilities.
- Inspecting storage drums, barrels, and containers and cleaning, using, or disposing of them as appropriate.
- Cleaning and decontaminating storage drums, barrels, and containers.
- Inspecting the tank farm and verifying the identity and quantity of the contents of each container.
- Transferring materials from processes or units to containers; in the case of continuous processes, ensuring that the transfer follows the specifications of the plant and customers.
- Verifying and preparing shipping papers or supplying the data to the appropriate shipping clerk.
- Loading materials onto ships, trucks, railroad cars, or other transportation vehicles.
- Handling all materials using safety, environmental, and health guidelines as outlined in the standard operating procedure (SOP) or material safety data sheet (MSDS).
- Cleaning up or arranging for cleanup of all spills.
- Responding to all emergencies.
- Developing and meeting shipment schedules.

P3 Modules

01 **REGULATORY ASPECTS OF HANDLING, STORING, AND TRANSPORTING CHEMICAL MATERIALS** 271

02 **HANDLING CHEMICAL MATERIALS** 273

03 **STORING CHEMICAL MATERIALS** 275

04 **TRANSPORTING CHEMICAL MATERIALS** 277

05 **OPERATING EQUIPMENT ASSOCIATED WITH HANDLING CHEMICAL MATERIALS** 279

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level PTs are expected to:

- Cite (or be able to locate) applicable regulations of Department of Transportation (DOT), Coast Guard, marine terminal, and all other pertinent agencies and organizations.
- Complete paperwork and reporting procedures for major regulatory agencies.
- Identify the safety and work requirements that are unique to specific industry areas and employers and be familiar with some of the differences.
- Use proper handling techniques for transferring materials from vessels, tanks, barrels, and other storage devices and identify proper personal protective equipment (PPE) to be used for transfer operations.
- Describe unique features of marine terminal procedures for general operations and handling chemicals.
- Describe physical properties of materials and effects of temperature and pressure on the transferability and storage of gas, liquid, and solid materials.
- Describe chemical properties of materials and effects of exposure to air and water that affect the transferability and storage of gas, liquid, and solid materials.
- Describe loading and unloading techniques appropriate for trucks, railroad cars, and other carriers.
- Describe transfer techniques for handling materials at marine terminals.
- Identify all the types, correct use, and proper labeling of containers used in chemical plants and refineries.
- Describe how tank storage works and describe the relationship of vapor pressure of the stored materials to safety and structural integrity of the tanks.
- Demonstrate standard container-labeling procedures.

Continued

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- Write an SOP describing unloading and loading procedures for different types of materials for at least two different modes of transportation.
- Describe cleaning and decontamination procedures for drums, barrels, and containers used with at least three different kinds of materials (excluding nuclear materials).
- Describe applicable federal and state regulations associated with shipping materials.
- Measure selected physical and technical properties such as vapor pressure, particle size distribution, color, and pH, according to American Society for Testing and Materials (ASTM) or other pertinent standards.

REGULATORY ASPECTS OF HANDLING, STORING, AND TRANSPORTING CHEMICAL MATERIALS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Apply appropriate safety and handling procedures as required by standard operating procedures (SOPs) and material safety data sheets (MSDSs) when handling, storing, and/or transporting materials.

02 Identify and define terminology used in SOPs for handling chemicals and MSDSs.

03 Identify regulating agencies at the federal, state, and local levels that are responsible for overseeing handling, storage, and transportation of chemical materials.

04 Read, interpret, and apply regulations and appropriate chemical hazard information, including explanations provided by common labeling systems.

05 Prepare appropriate labels for a variety of chemical materials.

06 Outline proper material handling and vessel decontamination procedures.

07 Apply Department of Transportation (DOT) regulations to common shipping and receiving procedures and to the equipment used for handling chemical materials, including materials with high vapor pressure.

Continued

P3.01

Recommended Competencies

08 Choose at least three products produced by local companies and describe handling and transporting requirements for each.

09 Apply Coast Guard and international maritime regulations to common receiving and shipping procedures and to the equipment used for handling chemical materials at marine terminals.

10 Select shipping/transportation forms from each regulating agency as appropriate for materials handled by the local chemical process industry (CPI) and, for a case study, complete each form.

11 Participate in writing a Hazard Communications (HAZCOM) program.

Local, state, and federal regulations play a major role in the chemical industry. It is the process technician's responsibility to be aware of these regulations so that chemical materials can be handled, stored, and transported safely. For example, a technician at a chemical manufacturing company was asked to load a tractor trailer with benzene. Before the loading began, the technician blocked the trailer wheels, locked the tractor trailer rig down, and purged the trailer of air in accordance with regulations. The technician then inspected the rig for highway worthiness, which included checking lights, turn signals, and tires. The technician noticed that the recaps on two of the rear tires were coming apart despite showing good tread. The technician felt that the two tires were not suitable for highway travel under state regulations and needed to be replaced. The driver agreed, and the loading was suspended long enough for the tires to be replaced.

P3.02

HANDLING CHEMICAL MATERIALS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify major classes of industrial chemicals, including petrochemicals, plastics, paper and pulp, and pharmaceuticals.

02 List major types of chemical hazards.

03 Categorize common commercial chemicals as elements, inorganic/organic compounds, and mixtures.

04 Identify the class of chemical and associated hazards from labeling used for common commercial chemicals.

05 Match formulas, symbols, chemical names, and common names for common commercial chemicals.

06 Use a chemical reference book to determine the formula, name, and basic properties of a variety of chemical materials of importance to the industry in the local area.

07 Identify common commercial chemicals that are considered to be corrosive, flammable, or combustible and give examples of proper handling/storage procedures for such materials.

08 Identify personal protection equipment (PPE) appropriate for handling several classes of chemical materials that are commonly found in the local/regional area.

09 Identify and compare the National Fire Protection Agency (NFPA), Hazardous Materials Identification Symbols (HMIS), and Department of Transportation (DOT) labeling systems.

10 Describe containment and cleanup and reporting procedures for containing and cleaning up spilled chemicals, including flammable, toxic, reactive, and corrosive materials.

Recommended Competencies

11 Identify problems related to handling/storing hygroscopic materials and give examples of proper handling for such materials.

Continued

P3.02

The risk of injury when handling hazardous materials can be greatly reduced by following proven safe work practices. One aspect of safe work practices is the proper use of personal protective equipment (PPE). For example, while sampling different types of hydrocarbons, a technician was wearing a full slicker suit, rubber boots, face shield, hard hat, and organic half-mask respirator, all sufficient PPE for collecting pure hydrocarbons. Later, however, the technician collected a sample of hydrocarbon that contained residual aluminum chloride ($AlCl_3$). The technician did not change to the PPE appropriate for this form of hydrocarbon, and the technician inhaled a small amount of acid gas. Fortunately, the technician suffered only from a short-term sore throat, but the consequences could have been much more serious.

P3.03

STORING CHEMICAL MATERIALS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Select storage facilities appropriate for each of the main classes of chemicals.

02 Identify industrial uses for the following storage/shipping containers and give examples of the use of each:
  - 5-gallon cans
  - 55-gallon drums (steel, plastic, stainless steel)
  - carboys
  - bottles (plastic, glass)
  - sample cylinders
  - 440-gallon chemtotes
  - gas cylinders
  - fiber packs
  - ammonia tanks

03 Describe types of materials used to construct storage containers/vessels and handling equipment for hazardous chemicals.

04 Correlate characteristics of boiling point, vapor pressure, and viscosity with choice of storage containers.

05 Describe the requirements of vessels and techniques used to store and handle gases.

06 Identify the purpose of tank diking and spill diversions.

07 Identify procedures for determining the suitability of a tank or vessel for storage of specified materials.

08 Identify common indicators of deterioration of tanks and other storage containers.

09 Given a set of conditions and materials, identify tanks or other containers most appropriately used for storage.

10 Identify at least five purposes for using storage tanks in chemical or petroleum processing and handling.

11 List steps and safety precautions appropriate for cleaning and purging tanks for hot work, entry, and disposal.

12 Operate valves, pumps, hoses, and filters to transfer materials to storage vessels from process equipment or other storage vessels.

Continued

P3.03

13 Describe functions of level, pressure, flow, and temperature instruments for storing chemicals.

Recommended Competencies

14 Given a variety of materials used locally with different vapor pressures, boiling points, corrosivity, and hygroscopicity, as well as other chemical and physical characteristics, describe techniques appropriate for sampling and storage.

15 Using a computer information system, develop a simulated inventory of storage containers, including all tanks, barrels, and drums; designate usage and availability of each; and compare with local industry applications and discuss any differences.

16 Using a computer information database, develop a simulated inventory system for stored materials; compare the inventory system with comparable ones used in the local industry and report any differences.

17 Identify uses of, methods of sampling from, pressure ratings of, and venting requirements appropriate for the following tanks:

- floating roof tanks
- high-pressure spheres and cylinders
- cryogenic tanks/bottles

18 Describe hazards involved in storing volatile chemicals and proper response to emergencies such as fire, spill, and contamination.

One of the responsibilities of a process technician is to understand the proper techniques for storing chemical materials. In particular, the technician must be aware of the properties of the chemical material and of the chemical storage containers and the circumstances under which the chemical is being stored. For example, a drum containing sulfuric acid needed to be taken out of service for repairs. Before repairs could be made, the 99% acid solution had to be moved to a temporary storage place. The technician understood that, because of the short residence time, the vessel did not need a special liner and determined that 55-gallon steel drums would be sufficient for the storage. A work team retrieved several drums and brought them to a staging area so that they could be filled with the acid. Upon inspection of the drums, however, the technician realized that the drums had been sitting outside and had condensation in them. Filling the wet drums with acid would have created a dangerous reaction, and the technician, knowing that the storage containers were inadequate, suspended the transfer until the drums were sufficiently dried.

P3.04

TRANSPORTING CHEMICAL MATERIALS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe appropriate techniques and suitable containers commonly used for shipping chemical materials.

02 Describe appropriate use of ground, rail, air, and water transportation for a variety of different kinds of materials; identify regulations associated with each.

03 Identify proper shipping modes for a variety of chemical materials based on quantity, volatility, toxicity, corrosivity, hazards for handlers, and environmental hazards.

04 Identify basic steps used in the transfer of bulk chemicals from one vessel to another.

05 Describe the procedure to move gas cylinders safely from one location to another.

06 Describe the value and application of the following items as they relate to transporting chemical materials:

- hoses
- pumps
- instruments
- compressors
- pumps
- piping connections

07 Write a standard operating procedure (SOP) for transporting specified chemical materials via a specified transportation mode.

08 Explain the purpose of a bill of lading.

09 Prepare materials for shipping, including selection of containers, preparation of labels, and completion of required paperwork.

10 Receive materials, using the appropriate SOP for loading and unloading procedures for each mode of transportation.

Continued

Recommended Competencies

11 Collect appropriate samples for identification and quality verification of the materials being received by applying appropriate SOPs.

12 Read and interpret special manuals applicable for marine terminals and describe special chemical materials handling requirements for loading and unloading at marine terminals.

13 Visit a local chemical plant and identify procedures used to receive and ship materials.

When chemical materials are in transit, they are not under the watchful eye of a knowledgeable process technician. Instead, they are in the hands of a shipper who may not know all of the characteristics of the chemicals. Therefore, the technician who loads the chemical must exercise care so that the shipper is not in a dangerous situation. For example, when a manufacturer used a tank truck to ship a product to a customer, the technician conducted an inspection of the tank. The chemical being shipped reacted violently with water, and the technician knew that the tank had to be clean and dry before loading. Upon inspection, however, the technician noticed a small amount of liquid in the tank. Further analysis proved that the tank truck had water and contaminants from the previous cargo. Although the customer wanted the chemical delivered as soon as possible, the technician called for another truck that was dry and clean. Even though this delayed the delivery, the shipper was not exposed to a dangerous environment.

P3.05

OPERATING EQUIPMENT ASSOCIATED WITH HANDLING CHEMICAL MATERIALS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify and describe the proper use of hand tools and hand-operated equipment used in handling chemical materials, including:

- hand truck/drum dolly
- valve wrenches
- mobile A-frame with chain-operated or hydraulic lifts, slings, cables, and boomers

02 Move drums safely from one location to another using hand trucks.

03 Identify and describe the proper use of light/heavy motorized equipment used in handling chemical materials, including:

- forklifts
- cherry pickers
- rail equipment
- fixed and mobile power lifts
- overhead cranes

Recommended Competencies

04 Use forklifts and cherry pickers.

05 Operate a power lift gate on a truck.

06 Operate cranes, including those used on overhead rails.

Process technicians' knowledge is beneficial not only to themselves, but to others as well. For example, a vendor was delivering gas cylinders containing high-pressure flammable gas to a production plant. The delivery person did not have a cylinder dolly and was instead improvising with a standard dolly. An accident involving the cylinders could have been very dangerous to the delivery person and other personnel in the plant. A technician asked the delivery person to stop moving cylinders long enough for a proper dolly to be located. The technician instructed the delivery person to use the cylinder dolly for the rest of the delivery, ensuring a safer work environment for the vendor and workers at the production plant.

P3

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 282
COMPUTER 283
COMMUNICATION 284

P3

MATH & STATISTICS

Handling, Storing, and Transporting Chemical Materials	MODULES				
	01	02	03	04	05
Read & Construct Graphs		✓	✓	✓	✓
Calculate Ratios		✓	✓	✓	✓
Perform Unit Conversions		✓	✓	✓	✓
Recognize Patterns from Data		✓	✓	✓	✓
Solve Single-Unknown Algebra Equations			✓	✓	✓
Calculate Means & Standard Deviations		✓	✓	✓	✓
Calculate Accuracy & Precision of Data Sets					✓

COMPUTER

Handling, Storing, and Transporting Chemical Materials	MODULES				
	01	02	03	04	05
Use a Computer Keyboard	✓	✓	✓	✓	✓
Access Database Information	✓	✓	✓	✓	✓
Develop & Maintain a Database		✓	✓	✓	✓
Use, Maintain & Develop Spreadsheets		✓	✓	✓	
Conduct On-line Literature Searches	✓				

COMMUNICATION

Handling, Storing, and Transporting Chemical Materials	MODULES				
	01	02	03	04	05
Oral Communication	✓	✓	✓	✓	✓
Written Communication	✓	✓	✓	✓	✓
Read & Understand Procedures	✓	✓	✓	✓	✓
Maintain Log & Notes		✓	✓	✓	✓
Keep Records			✓	✓	✓
Write Memos & Letters				✓	✓
Give Clear, Concise Instructions		✓	✓	✓	✓
Report Data		✓	✓	✓	✓
Maintain Accurate Notebook		✓	✓	✓	✓
Read & Prepare Diagrams			✓	✓	✓
Conduct Literature Searches	✓				
Read Technical Manuals & Journals	✓	✓			

OPERATING, MONITORING, AND CONTROLLING CONTINUOUS AND BATCH PROCESSES

Introduction

Process technicians (PTs), often referred to in plant operations as process operators, are responsible for operating, monitoring, and controlling the operations and processes used to make, blend, and separate chemical materials in a plant. Often, PTs are assigned to a specific unit within a process operation for a long time. PTs are the prime source of process information for engineers and managers seeking to ensure competitiveness and efficiency. To operate the process most effectively, the PT requires a fundamental understanding of how chemical processes work, the building blocks or unit operations of processes, the chemistry that takes place in the processes, and the technology used to control and optimize processes.

The modules developed for this Critical Job Function are designed to provide the PT with general core knowledge of chemical manufacturing processes as well as detailed knowledge and skills applicable to working safely and effectively in a plant. A mix of classroom, laboratory, pilot plant, and actual plant experiences constitute a complete educational program for PTs.

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TASKS

Tasks conducted by PTs related to this Critical Job Function include:

- Reviewing and properly interpreting all checklists associated with a process.
- Completing all required reports to describe process activities, discrepancies, and maintenance.
- Adjusting control equipment as specified by procedures, setting operating parameters, and identifying abnormal conditions that require reporting.
- Checking equipment to ensure safety for electrical loading, physical stressing, and temperature variation.
- Starting up process according to specified procedures.
- Monitoring operating parameters by reading gauges, instruments, and meters, and logging or otherwise recording the information as necessary.
- Adjusting operating parameters to optimize conditions appropriate to the process.
- Recognizing and correcting any deviations.
- Responding to any alarms.
- Collecting appropriate samples.
- Conducting on-site inspections.
- Submitting samples for analysis.
- Recording and reporting data.
- Shutting down processes according to procedures.
- Shutting down processes in emergency situations.
- Maintaining piping networks.
- Participating in developing/revising standard operating procedures (SOPs).
- Calculating and documenting production rates.
- Training new technicians.
- Maintaining quality control charts to determine whether the plant is under control.

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level PTs are expected to:

- Describe characteristics of continuous and batch processes.
- Describe two or three major industrial continuous and batch processes, including common chemical, refinery, water, and waste treatment processes by: (1) describing the operation of each; (2) characterizing chemical/physical properties of materials that are important to the processes; (3) writing molecular formulas and chemical structures for substances involved in the processes; (4) describing chemical reactions involved in each process; (5) describing chemical equilibrium, kinetics, and chemical reactivity relationships that characterize the processes or may affect safety; and (6) identifying relevant environmental regulations and safety concerns.
- Read process diagrams and include: (1) descriptions of various components and streams of a continuous process; (2) identification and descriptions of the types and operations of control loops and sample collection devices; and (3) identification of typical valves, pumps, and other equipment according to type and usage.
- Draw a simplified process diagram for a variety of operational needs.
- Demonstrate ability to follow common operating procedures and use safety information, such as that provided by material safety data sheets (MSDSs).
- Start up, operate, and shut down a process.
- Write the documentation for an operating procedure that meets Occupational Safety and Health Administration (OSHA) requirements.
- Describe a troubleshooting strategy for a complex process, given a variety of upset conditions.
- Describe the operation, characteristics, and limitations of process measurement equipment, such as thermocouples and other on-line instruments.
- Describe process flows, both gas and liquid streams.
- Describe the concepts associated with process optimization.

Continued

P4
Modules

01 INTRODUCTION TO PROCESSES 289
02 PROCESS CHEMISTRY . . . 291
03 PROCESS DIAGRAMS . . . 293
04 DISTILLATION AS AN OPERATION (Single-Phase Separation) 295
05 ABSORPTION, ADSORPTION, FILTRATION, ION EXCHANGE, AND EVAPORATION OPERATIONS (Dual-Phase Separation) 297
06 EXTRACTION AS AN OPERATION 299
07 REACTIONS/REACTORS AS AN OPERATION 301
08 FLUID FLOW AND FLUID MIXING 303
09 HEATING AND REFRIGERATION 305
10 THE UNIT OPERATIONS AS PART OF A PROCESS . . . 307
11 PROCESS CONTROL 309
12 OPERATING A PROCESS . . 311
13 PROCESS OPTIMIZATION 313
14 ENVIRONMENTAL CONTROL 315
15 WASTE WATER TREATMENT 317

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- Describe when, where, and why samples are taken for analysis and how the sampling techniques relate to quality products.
- Describe different kinds of electric motors and demonstrate capabilities to start up and to shut down motors.
- Describe various types of heat exchangers and demonstrate operation of each.
- Demonstrate ability to perform filtrations, extractions, distillations, drying, blending, milling, and packaging.
- Retrieve data and information, as required.
- Provide shift transfer notes.

P4.01

INTRODUCTION TO PROCESSES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe why the chemical industry is referred to as the chemical process industries (CPI).

02 Define characteristics of a continuous process; give examples from the CPI.

03 Define characteristics of a batch process; give examples from the CPI.

04 State similarities and differences between continuous and batch processes.

05 Starting with a simplified flow chart of a complex continuous process, identify the unit operations that constitute the process.

06 Starting with a simplified flow chart of a complex batch process, identify the unit operations that constitute the process.

Recommended Competencies

07 Describe how, in a continuous process, there is continuous flow of gases, liquids, and/or solids; how different parts of the plant interrelate with one another; and how a problem in one area/unit of the plant may affect others.

08 Describe how in a batch process the interaction of different components in a plant affects each other.

P4.02

PROCESS CHEMISTRY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Define "chemistry."

02 Define and provide examples of "atoms" and "molecules."

03 Define and give examples of "chemical compounds."

04 Define and give examples of "chemical mixtures."

05 Describe gases, liquids, and solids in terms of their properties.

06 Differentiate between organic and inorganic materials; give examples of each.

07 State both standard and commercial names for common organic and inorganic compounds and write formulas for each.

08 Given the periodic chart, identify particular characteristics for individual elements (i.e., atomic weight, atomic number, atomic structure, metals, nonmetals, gases).

09 Given a particular element, draw a model of its atomic structure, including the number of protons, neutrons, and electrons.

10 Calculate molecular weight.

11 Define "stoichiometry."

12 Write and balance simple chemical equations and relate to chemical reaction.

13 Calculate pressure, temperature, and volume relationships using the gas laws, including:
  - ideal gas law
  - Boyle's law
  - Charles's law

14 Define terms associated with solution chemistry, including:
  - solubility
  - partition coefficient
  - liquid
  - liquid equilibrium

15 Make mass to mole conversions.

16 Describe mass and energy balances and the fundamental laws that apply.

Continued

17 Calculate the expected yield of material, given a chemical reaction.

18 Correlate the molecular structure of compounds with physical properties, particularly boiling point, vapor pressure, and density/specific gravity.

19 Describe differences between ionic and covalent bonding.

20 Define and give examples of "exothermic" and "endothermic" reactions as they relate to process operation.

21 Describe equilibrium and discuss effects of LeChatelier's principle.

22 Define "steady state" as applied to continuous processes.

23 Determine cycle time for a batch process.

24 Distinguish among cracking, polymerization, neutralization, substitution, decomposition, and reduction/oxidation chemical reactions and describe the chemical and physical characteristics that are important to controlling and handling these raw materials and products.

Recommended Competencies

25 Identify three major processes of interest to local industries; write the chemical equations that relate to the chemistry of the processes; describe the chemical and physical properties of materials used in the processes; and write the temperature/pressure relationships for the processes.

A process technician who is knowledgeable about process chemistry can troubleshoot complicated problems and offer practical solutions. For example, the waste byproduct from a manufacturing plant had to be neutralized before being pumped into biological treatment ponds. As part of increased plant operations, the chlorine concentration and flow rate into the process reactor needed to be increased as well. When the plant was put on line with the increased parameters, the computer immediately identified a low pH on the waste container pH control tag. By understanding process chemistry, the technician narrowed the troubleshooting search, including reviewing the logbook for latest changes to the system, checking the computer software for possible glitches, checking to make sure that the neutralizer was the correct concentration, and calculating the amount of neutralizer needed to neutralize the excess chlorine that was being sent to the bio pond. As a result, the technician concluded that the system was too small for the new parameters and that equipment modifications were necessary before the increased production could be continued.

P4.03

PROCESS DIAGRAMS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Interpret process-related diagrams, including flow sheets; material and energy diagrams; logic diagrams; block flow diagrams; and piping and instrumentation diagrams (P & IDs).

02 Interpret symbols, icons, and abbreviations for all major components of processes and for all major pieces of equipment.

03 Draw schematic diagrams for locally important processes, including flow sheets, material and energy diagrams, logic diagrams, block flow diagrams, and P & IDs, placing proper symbols and icons as required; use directional arrows to indicate flow.

04 Use computers to access process diagrams.

Recommended Competencies

05 For a local industry, identify process components on a flow diagram; relate to similar flow diagrams available from literature sources; and note and discuss any differences among the flow diagrams.

For process technicians who need to learn, understand, or reconfigure an existing process, diagrams are an invaluable tool. For example, in preparation for plant expansion, a series of pipes, valves, and instruments needed to be rerouted. A technician was asked to review the problem and propose a solution. The technician retrieved several different versions of the process diagrams and read them all carefully. By understanding the diagram symbols, the technician was able to sketch alternative routes that did not obstruct existing valves and instruments. By picturing the diagram three-dimensionally, the technician was able to sketch creative solutions that would not alter the process. After reviewing the diagrams and the alternative solutions, the technician decided on one particular configuration. The proposed solution was later approved because it accommodated the pending expansion, did not disrupt existing processes, and offered minimal downtime.

DISTILLATION AS AN OPERATION (Single-Phase Separation)

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the basic principles of distillation.

02 Describe the relationship of boiling point and vapor pressure to the process of distillation.

03 Identify feed, product, reflux, heating, and coolant streams associated with distillation in continuous and batch processes.

04 For both continuous and batch processes, describe purposes of and differences between distillation separations involving:
- packed columns
- trayed columns
- vacuum
- atmospheric
- azeotropic
- non-azeotropic
- steam stripping
- binary fractionation
- high temperature
- cryogenic

05 Describe the relationship of boiling point and vapor pressure as they relate to each in 04 above.

06 Relate vapor pressure and partial pressure quantitatively to distillation column operating conditions.

07 Using vapor pressure curves, determine atmospheric temperature/pressure relationships that set the operating conditions for distillation columns.

08 Identify equipment commonly used in distillation and describe the purpose of each type.

09 Identify common types of distillation trays and describe the functional differences among them.

10 Conduct a laboratory distillation to separate multiple components of a mixture and plot a boiling point/fraction curve.

Continued

11 Describe the importance of heat and cooling sources to the distillation process.

12 Describe how product purity and process efficiency relate to temperature profile, differential pressure, and reflux ratios of a distillation column.

13 Identify several major industrial distillation processes; describe materials involved and the process used for each in terms of distillation equipment.

14 Calculate mass and energy balances for distillation processes.

15 Solve mass and energy balance problems under steady-state conditions.

Recommended Competencies

16 Visit a plant to observe the operation of a commercial distillation tower; review the data collected, make notes of observations, record analytical results, and prepare a report that fully characterizes the operation.

17 In a pilot plant and/or using simulations, set up the conditions for a distillation. Start up, operate, and shut down the distillation while collecting all measurements required to perform mass and energy balances.

Distillation is a very common separation unit operation in the chemical process industries (CPI). Distillation columns frequently become limitations to product quality, and technicians must understand how the entire process operates and where to troubleshoot. In one example, a process technician noticed that the separation did not meet specifications. The technician checked the instrumentation and concluded that it was operating properly. The technician then checked the flow rates of the streams that crossed the distillation system and noticed that one stream was lower than the specification. Upon further investigation, the technician found a small leak upstream, which was causing the problem. The technician reported the leak to the maintenance team, who was able to repair the leak and get the process back into full operation.

P4.05

ABSORPTION, ADSORPTION, FILTRATION, ION EXCHANGE, AND EVAPORATION OPERATIONS (Dual-Phase Separation)

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Define "absorption," "adsorption," "filtration," "ion exchange," and "evaporation" as unit operations.

02 Identify the integral parts of absorption, adsorption, filtration, ion exchange, and evaporation units (packing materials, distributors, screens, filter elements, exchange resins, etc.).

03 Describe several ways in which absorption, adsorption, filtration, ion exchange, and evaporation units are used in continuous and batch industrial processes.

04 Identify major types of filters and strainers used in the chemical process industries (CPI).

05 Identify types of dryers for adsorption used in the CPI.

06 Write basic chemical reactions that describe ion exchange and give several examples of how ion exchange is used in industrial processes (particularly for water treatment).

07 Identify several types of ion exchange and the kinds of materials used for each.

08 Describe major types of evaporators and crystallizers and compare the operation, efficiency, and major applications.

09 Identify several industrial processes that use evaporation in one or more operations.

10 Apply a variety of absorption, adsorption, filtration, ion exchange, and evaporation techniques in the laboratory and pilot plant.

Continued

P4.05

Recommended Competencies

11 Conduct an experiment to show pressure drop relative to service time of use of a filtration cartridge.

12 Calculate capacity limitations for absorption, adsorption, filtration, ion exchange, and evaporation units.

13 Describe the operation of and equipment used for settling, thickening, clarifying, and decanting; give examples of the use of each and determine results for each using typical process data.

14 Describe steps in preparing raw water for use as makeup to cooling towers and boilers (i.e., clarification, filtration, ion exchange, deaeration, chemical addition, etc.).

15 Describe packed-bed separation equipment.

Technicians should always be aware of changing plant conditions. Process quality, plant environment, and equipment operation are all important conditions that a technician can usually anticipate and act upon before an upset disrupts the process. Adsorption, for example, is one of the critical activities that must be monitored at all times—especially during cold weather. At a plant, a technician was aware that an oncoming weather pattern was going to bring temperatures below freezing for several days. For the gas to flow continually through the process during the period of low temperature, the technician took special precautions with the adsorption process. Moisture levels in the gas lines that exceeded 1 ppm could promote freezing, pipe blockage, and damage to the equipment and final product. The technician analyzed the system and confirmed that it was working properly. Instruments were giving good readings, and the supply of activated carbon (active adsorber) was good. Throughout the cold spell, the technician continually monitored the process and was prepared to act quickly if the adsorption process was not working. The technician was prepared for the conditions and ensured that the adsorption process was working.

P4.06

EXTRACTION AS AN OPERATION

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify feed, product, and intermediate streams associated with extraction in continuous and batch processes.

02 Differentiate between types of extraction processes, including liquid/liquid, liquid/vapor, and liquid/solid.

03 Define partition coefficient.

04 Identify and describe operational characteristics of major equipment used in extraction, including columns, mixer/settlers, etc.

05 Define the roles of the carrier solvent, solute, extract, and raffinate in extraction processes.

06 Identify several common major industrial extraction processes; describe the materials involved and the extraction process used for each in terms of type, solvent, and equipment.

Recommended Competencies

07 Conduct laboratory extractions for a variety of organic and inorganic materials and determine the distribution coefficients.

08 In a pilot plant and/or using simulations, set up the conditions for extraction, start-up, operation, and shutdown, while collecting all measurements required to perform mass and energy balances.

09 Observe a commercial extraction unit at a local company; review the data collected, note observations, record analytical results, describe how the extraction relates to the rest of the process, and prepare a report.

10 Identify common types and the purpose of column packings, packing supports, and distributors.

Continued

P4.06

Extraction, the process by which different substances are separated by incorporating a solvent, is often used when the substances are heat sensitive, are at low concentrations, or have low volatility. Phenol, ether, ketones, and aromatics are examples of solvents technicians must choose from when conducting extractions. Choosing the appropriate solvent for the process is critical to the effectiveness and safety of the extraction. At a petroleum refinery, for example, a technician was asked to remove sulfur compounds from a petroleum stream. The technician chose a solvent that was specifically formulated for the extraction. Had the technician used anything other than this solvent, the separation would not have been completely successful. Residual sulfur compounds would have damaged the product in later phases of the production.

REACTIONS/REACTORS AS AN OPERATION

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Given a chemical equation, describe the reaction.

02 Write several chemical reactions used in major batch and continuous industrial processes; use classical reactions in several categories as well as those of specific interest to the local industries.

03 Balance simple chemical equations relevant to major industrial processes.

04 Calculate percent yield for industrial reactions from feed and product data typically available for a process.

05 Relate mass and energy balance to reaction design and control, both qualitatively and quantitatively.

06 Calculate feed requirements for a required yield reaction.

07 Identify the impact of changes in temperature, pressure, catalyst activity, and concentration on chemical reactions in processes common in the local area.

08 Give examples of common endothermic and exothermic reactions for processes.

09 Define "catalyst"; identify examples of catalysts used in local industrial processes; describe the effects of the catalysts on the reactions involved; and determine the expected impact of, causes of aging of, and poisoning of the catalysts.

10 Identify equipment such as agitators, autoclaves, distributors, grids, and baffles that are used in reactors.

11 Identify common types of reactors and describe typical applications of each one (including stirred kettles, autoclaves, and furnaces).

Continued

12 Characterize several types of mixing environments and describe the equipment used in each.

13 Describe major steps in starting up and shutting down batch and continuous reactors safely.

14 Describe symptoms of abnormal reactor operation.

15 Relate the rate of reaction to the following conditions: catalyst contact, mixing, pressure, and temperature.

Recommended Competencies

16 Draw diagrams of fixed-bed and fluidized-bed reactors.

17 In laboratory or pilot plant, set up the necessary equipment and conduct reactions representing major industrial processes of interest to the local industry.

Often, process technicians are responsible for monitoring an entire reaction. Recognition of upstream changes in reactor variables, in particular, allows the technician time to adjust reactor conditions and keep the operation under control. Technicians who adjust quickly to subtle changes in the process often are able to prevent runaway conditions or the production of off-spec product. In an ethylene plant, converting acetylene, a contaminant, into ethylene is a critical step toward purification. A technician carefully monitored the catalytic hydrogenation in which the acetylene is converted to ethylene. At one point, the reaction began to speed up as a result of plant conditions. The technician knew that too rapid a reaction would incrementally increase the temperature of the process and lead to a runaway situation. The technician quickly brought the temperature down to its optimal level and was able to maintain the process.

P4.08

FLUID FLOW AND FLUID MIXING

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify major equipment associated with fluid flow, including valves, fans, blowers, pumps, compressors, and vessels; describe the operation, use, and function of each.

02 Use diagrams to describe operational characteristics of centrifugal and positive displacement pumps; state the common use and limitations of each.

03 Repack pump seals.

04 State causes of head/pressure loss in a piping system; state ways to minimize losses.

05 Distinguish among the following valve types: globe, needle, gate, butterfly, diaphragm, check, ball, plug, and automatic pneumatic. Identify the components, characteristics, use, and limitations of each.

06 Describe components and principles of operation (using sketches) of fans, blowers, positive displacement, and centrifugal compressors.

07 Demonstrate ability to isolate pipes/pipe joints and break flanges using basic hand tools, such as wrenches, sockets, and pipe and valve wrenches.

08 Describe the function and operation of protective devices (i.e., rupture disks and relief valves).

09 Recognize causes of problems associated with pumps, fans, blowers, and compressors.

10 Identify a potential problem in a fluid flow system and outline methods to correct and minimize the effect on the pressure.

11 Locate various pieces of equipment associated with fluid flow on a process diagram from local industry.

Continued

12 Describe the principle of fluid mixing and characterize efficient mixing.

13 Identify equipment used for efficient fluid mixing.

Recommended Competencies

14 In a pilot plant or laboratory, demonstrate ability to take common equipment, associated with fluid flows and mixing, out of service and return to service.

15 Distinguish between gauge pressure and absolute pressure and convert pressure readings between the two types of pressure.

Process technicians are responsible for making several tours or "rounds" of a unit in a plant. During these rounds, technicians observe the equipment associated with fluid flow, including the valves that control flow rates. During a unit shutdown in a plant, a team of maintenance technicians replaced several leaking gate and check valves. The process technician responsible for the unit startup checked the equipment lineup and noticed that a check valve had been installed backwards. The technician promptly had the valve reversed before startup. Had a startup been attempted with the valve installed backwards, there would have been no flow in the system, resulting in a significant loss of time and effort. The alertness of the process technician permitted an orderly and timely startup.

P4.09

HEATING AND REFRIGERATION

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Outline principles of heat transfer in terms of conduction, convection, and radiation.

02 Outline the refrigeration process cycle.

03 Describe major types of industrial heaters; compare the operation and efficiency of each.

04 Describe major types of evaporators and crystallizers; compare the operation and efficiency of each.

05 Identify the four basic types of heat exchangers used in the chemical process industries (CPI).

06 Quantitatively describe the operation characteristics of a variety of heat exchangers and factors that affect their efficiency.

07 Calculate heat transfer rates from process data for major types of heat exchangers; describe the flow characteristics in each type; and compare the operation, efficiency, and typical applications of each.

08 Describe the operation of natural draft and forced draft cooling towers; qualitatively compare the operation, efficiency, and typical applications of each; and quantitatively determine the cooling range and approach to wet-bulb temperature.

09 Locate equipment associated with heating and refrigeration on a process diagram obtained from a local industry.

10 Prepare a process diagram that shows equipment associated with heating and refrigeration.

Continued

P4.09

Recommended Competencies

11 Describe the types of burners used in process furnaces, with particular emphasis on efficiency and control of combustion contaminants such as unburned hydrocarbons, carbon monoxide, and nitrogen oxides.

12 In a pilot plant, or using a simulator, remove heating and cooling equipment from service and place back into service.

13 Describe the operation of natural, forced, and induced draft furnaces; qualitatively compare the operation, efficiency, and typical applications of each.

Components of heating and refrigeration units are fairly universal. Most types of refrigerator loops include equipment such as compressors, condensers, accumulators, throttle valves, and evaporators and chemicals such as propane and propylene. Consequences of neglecting a system operation could be severe; therefore, it is important that the process technician understand how these components operate. For example, in a process unit, an evaporator outlet stream was slowly approaching a critical temperature. The technician monitoring the stream knew that if it was not kept below 50° F, polymerization could occur, resulting in off-spec product. Initial investigation suggested that not enough refrigerant was available to maintain that temperature. Although many components of the refrigeration system could be at fault, the technician suspected that the refrigerant reservoir was low. The technician checked the refrigerant reservoir and found that it was, in fact, dangerously low. The technician added refrigerant to the reservoir and performance was restored to the target conditions.

P4.10

THE UNIT OPERATIONS AS PART OF A PROCESS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Use a block diagram to relate the various units required by at least three industrial processes of interest to the local industry.

02 Visit an industrial plant that operates continuous and batch processes; with a process technician or chemical engineer, identify and diagram the operation of each of the unit operations mentioned in the modules for this Critical Job Function; describe each unit in terms of its function in the process; identify potential problems, cautions, etc., associated with each unit; prepare a report that describes the role of each unit operation in the process(es) examined above; and deliver the report orally to a class group and to others as appropriate.

Processes are composed of several different units which, integrated effectively, can be very productive and efficient. The technician's awareness of the overall process is invaluable to plant operations. For example, power generation, although not a component of the final product, is an imperative part of the process, and the technician is responsible for ensuring that the power supply is sufficient for plant operations. Power can be generated either on site or off site. In either case, the technician will be the first to know whether power is fluctuating or failing. It is then the technician's responsibility to contact the proper personnel, who can correct the problem.

PROCESS CONTROL

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify control loops in a piping & instrumentation diagram (P & ID) and describe their function as part of a process.

02 Identify and describe uses of common types of control loops, including cascade, master/slave, summation, etc.

03 Identify primary components of control loops, including sensors, transmitters, controllers, and final control devices; describe the function of each.

04 Identify several common types of instruments used to measure temperature, flow, pressure, level, and analytical parameters, and for each
- describe common calibration procedures
- determine the accuracy and precision
- demonstrate methods of switching between automatic and manual operation
- demonstrate how the instruments are commissioned and decommissioned into and out of control loops
- identify what might cause faulty readings

05 Identify and describe uses of common types of manual equipment controls for temperature, pressure, level, and flow.

06 Using a control loop in a pilot plant (or simulation), collect and record flow, temperature, pressure, and level data on a control chart; calculate upper and lower control limits.

07 Visit a control room at a local industry; observe how each of the instruments is linked through control loops and sensed in the control room with computer interfaces.

08 Identify the variables used in process control and relate how changes in these variables affect the overall process.

Recommended Competencies

09 View control loops and associated instruments during a process and describe the function of each in the process.

Continued

P4.11

Automation is commonly used in monitoring processes; however, even the most sophisticated systems should be watched carefully by process technicians. Furnaces, for example, operate with two basic inputs: fuel and oxygen. Many furnaces have built-in instruments that measure the temperature and automatically adjust the fuel and oxygen flow. A technician noticed that the outlet temperature gauge was giving an unusually low temperature. Upon further investigation, the technician noticed that the fuel rate was very high. The technician concluded that the entire process was in a dangerous spiral. The temperature output gauge was recognizing a lower temperature, which caused the fuel control valve to open wider and input more fuel to the process. As a result, more and more fuel was being pumped into the process without the sufficient oxygen for combustion. The technician recognized that this dangerous situation compounded every minute that the furnace was operating. If the process got out of control, it would be extremely difficult to contain. Fortunately, however, the technician manually closed off the fuel valve and carefully monitored the process until the excess fuel was burned. The technician also suggested that the furnace be checked manually on a regular basis so that such an occurrence would not be repeated.

OPERATING A PROCESS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Demonstrate ability to apply the information provided by material safety data sheets (MSDSs) to a broad variety of common industrial chemical processes (include both batch and continuous processes).

02 Demonstrate ability to use the personal protective equipment (PPE) required for a variety of processes of interest to local industry.

03 Using a simulation, start up and operate and safely shut down processes useful to local chemical industry.

04 Describe operator safety responsibilities associated with abnormal plant conditions.

05 Monitor a process in a pilot plant or on a simulator; determine that the needs indicated by MSDSs and operating specifications are satisfied; record the appropriate data; and adjust the process as required.

Recommended Competencies

06 Collect samples, perform analyses to monitor the pilot plant process, and make adjustments as required to comply with the safety needs identified by the applicable MSDSs and operating specifications.

07 Shut down the pilot plant process and clean up for next use.

08 Compare the operation of the pilot plant process with a comparable full-scale process at a local plant; obtain written operating procedures for the process; observe the process in operation; and write a report for fellow students that compares the plant operation with that of the pilot plant.

Continued

P4.12

During the engineering of a plant and subsequent safety and hazard reviews, the plant is designed to provide all possible safeguards and responses to normal shutdown and startup procedures and nonroutine (abnormal or emergency) operations. Training of process technicians in these critical operations is an important and ongoing requirement. Normally scheduled shutdown and startup operations are planned well in advance to accomplish the objectives in a safe and efficient manner. Such planning and operation procedures avoid emergency shutdown or severe offset and product interruption. Sustained loss of certain utility systems such as electric power, cooling water, or instrument air will normally require emergency shutdown of the entire unit. Failure of major equipment items can also cause upset. Experienced technicians who understand the entire process, including the pace and sequence of steps that must be carried out in emergencies, are better able to handle emergency situations.

P4.13

PROCESS OPTIMIZATION

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the concept of process optimization.

02 For a specified process, identify steps required to optimize the process for the changing quality of starting materials and feedstocks and for the required product quality.

03 Correlate purity of output with process conditions and materials used in the process.

04 For a given process, calculate the effects of adjustments in flow rate, pressure, and temperature on the output quality and quantity.

05 Collect, chart, and analyze process data and apply statistical quality control principles.

06 Determine theoretical and actual production rates and calculate production efficiency for a process.

07 Determine theoretical and actual energy requirements for a given process.

08 For a specified process, identify the following types of optimization and conditions when each is most appropriate:

- increase yields
- decrease raw materials cost
- decrease energy costs
- increase product output
- improve product purity
- improve process throughput
- minimize waste

Continued

P4.13

Recommended Competencies

09 Determine cycle time for a batch process and residence time for a continuous process and identify ways of reducing time.

10 Correlate each of the types of optimization in P4.13.08 with plant economics and, with a team, develop an optimization program for each type.

11 For a specified process, develop a waste minimization program as part of optimization.

In the operation of a distillation unit, the process technician is responsible for optimizing the process in terms of cost energy and product output, which can result in lower costs. At a plant, two products were being separated by distillation. The overhead product had to meet product specifications of 95% purity. On-line analyzers showed that the plant was producing a 99% pure product. To optimize the process, the process technician lowered the reflux flow rate (decreasing the reflux ratio), thereby increasing the output. By doing this, a lighter load was placed on the reboiler, allowing the technician to decrease the amount of steam and lowering energy costs. After making these adjustments, the product purity decreased to 97%, but stayed above the 95% purity threshold, providing a more efficient, lower cost operation.

P4.14

ENVIRONMENTAL CONTROL

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Know the basics of Environmental Protection Agency (EPA) regulations.

02 Identify major air, water, noise, and ground pollutants associated with various industrial processes.

03 Identify processes and equipment that are major sources of air, water, noise, and ground pollutants.

04 Describe major environmental control equipment used to minimize pollutants for a variety of industrial operations; give examples for air, water, noise, and ground pollutants.

05 Describe the characteristics of particulates.

06 Describe the use and operation of equipment used to remove particulates.

Recommended Competencies

07 Choose a major pollutant and describe the source, control equipment used, and impact of the equipment on the environment (SO_x, NO_x, ground-level hydrocarbons would be appropriate).

Water used in a process often becomes contaminated with chemicals and requires elaborate clean-up before reuse. Waste water treatment must meet an "oxygen demand" level so that fish and other organisms are sustained. Total organic carbon (TOC) content of waste water is one measure of oxygen demand. To comply with regulations, a plant installed an elaborate stripping tower system that used a stream to remove organic compounds from waste water. Area drains from a section of the unit that contained organic carbons were collected in a storage tank and pumped to the stream stripping tower. A process technician observed that by installing a dedicated collection system to drain organic compounds, rather than draining to a sewer, considerable savings in costs and improvements in water quality could be obtained. The collection system was installed, and organic compounds were piped directly to the stripping tower. Pumping costs were reduced and the stream rate decreased because of the reduced quality of the diluted water. The TOC content of the stripped water decreased substantially, which significantly improved the operation of the plant aeration facility.

P4.15

WASTE WATER TREATMENT

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Trace water usage in a plant using a process diagram.

02 Differentiate between storm water, waste water, and sewage; describe the relationship of each to the water management cycle.

03 Determine sources and uses of water in plants.

04 Measure flow rates in waste water systems.

05 Sample influent and effluent streams.

06 Test for pH, solids, color, flow rate, total organic carbon (TOC), and settling rate using procedures specified by regulations.

07 Describe primary, secondary, and tertiary treatments; give examples of each.

08 Monitor the operation of a waste water treatment plant; under the guidance of an operator, make flow rate and analysis measurements on the waste water; and describe impacts of unit operations on waste water treatment.

Recommended Competencies

09 Under the direction of an operator, make necessary adjustments to a waste water plant or simulator.

10 Identify conditions for which the following treatment methodologies are appropriate: screening, settling, aeration, biological, dissolved-air flotation, pH correction, and oil/grease skimmers.

To comply with environmental and health regulations, refinery and chemical process units must treat effluents with chemical and mechanical systems. Process technicians are often responsible not only for monitoring this process but for continually seeking ways to reduce the amount of water used. For example, a technician in a petroleum refinery was informed that production would be increased. Despite the fact that the existing waste water treatment would be able to manage the increased production, the quantity of waste water could put the plant dangerously close to environmental control limits. Not wanting to run the risk of exceeding the regulations, the technician sought out a solution. After discussion with colleagues and supervisors, the technician decided to carefully review the process. The technician increased the chemicals in the process but did not increase the amount of water. After several small-scale test runs, the technician concluded that the alternative process would clean the water sufficiently.

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 320
COMPUTER 321
COMMUNICATION 322

MATH & STATISTICS

Operating, Monitoring, and Controlling Continuous and Batch Processes	MODULES														
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Read & Construct Graphs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Calculate Ratios	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perform Unit Conversions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perform Calculations Using Exponents		✓		✓	✓	✓	✓	✓	✓		✓	✓			✓
Perform Calculations Using Roots		✓		✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
Perform Calculations Using Logarithms		✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Use Appropriate Significant Figures		✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Recognize Patterns from Data		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Solve Single-Unknown Algebra Equations				✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Solve Simultaneous Equations		✓		✓	✓	✓	✓	✓	✓		✓		✓		
Solve Quadratic Equations							✓				✓		✓		
Calculate Means & Standard Deviations		✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Calculate Accuracy & Precision of Data Sets													✓		
Determine Control Limits		✓			✓	✓	✓		✓		✓	✓	✓	✓	
Determine Detection Limits													✓		

COMPUTER

Operating, Monitoring, and Controlling Continuous and Batch Processes	MODULES														
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Use a Computer Keyboard	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Access Database Information		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Develop & Maintain a Database				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use, Maintain & Develop Spreadsheets				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Use Graphics Software			✓												
Use Microprocessors				✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Use Statistical Software				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Transfer Data to & from Remote Databases				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Conduct On-line Literature Searches	✓														

COMMUNICATION

Operating, Monitoring, and Controlling Continuous and Batch Processes	MODULES														
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Oral Communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Written Communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
Read & Understand Procedures	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintain Log & Notes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Keep Records				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Write Memos & Letters				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Write Technical Reports												✓	✓		
Give Clear, Concise Instructions				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Report Data				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintain Accurate Notebook				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Read & Prepare Diagrams			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Write Methods				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Conduct Literature Searches	✓														
Read Technical Manuals & Journals	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

PROVIDING ROUTINE AND PREVENTIVE MAINTENANCE AND SERVICE TO PROCESSES, EQUIPMENT, AND INSTRUMENTATION

Introduction

Maintenance is essential to the efficient operation and functioning of a chemical processing industry (CPI) plant or operation. If performed properly, routine and preventive maintenance enhances safety and improves the efficiency of the operation. Emissions, leaks, and unplanned shutdowns are also reduced. In total, high costs and lost profitability associated with lost production are reduced. In large plants, maintenance is usually performed by specialists trained to maintain specific equipment and instruments. In smaller plants, the process technician (PT) is responsible not only for running but, frequently, for maintaining the overall operation. In both types of plants, the technician's role in requesting/performing maintenance and implementing maintenance schedules is critical to ensuring continuous operation.

Working knowledge of basic maintenance techniques is essential if the technician is to participate in turnarounds or make necessary adjustments when processes deviate from normal conditions. PTs are the first defense for recognizing the need for maintenance, proactively heading off minor problems before they become major upsets, correcting deteriorating situations at the onset, and, if not performing the maintenance tasks, arranging for them to take place.

Modern chemical processes use on-line controls for temperature, pressure, flow, level, and analytical targets. These on-line control instruments act as additional eyes and ears of technicians, aiding in the maintenance of a continuous, economical, safe, and stable mode of operation. Malfunctioning instruments can lead to upsets, equipment failure, hazardous conditions, and environmental incidents. Consequently, PTs must have a working knowledge of instrumentation, particularly how to recognize abnormal indications and behavior and how to protect the operation from instrument-induced upset.

The modules developed for this Critical Job Function are designed to emphasize the importance of routine and preventive maintenance to the overall work of the technician.

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TASKS

Tasks conducted by PTs related to this Critical Job Function include:

- Reading and following all standard operating procedures (SOPs) associated with the maintenance of processes, equipment, and instruments before starting any work.
- Observing, communicating, and recording any deviations from normal operations of processes, equipment, and instrumentation.
- Initiating work requests.
- Implementing and developing, if necessary, a preventive maintenance schedule.
- Inspecting equipment.
- Preparing equipment for maintenance.
- Following maintenance schedule developed by plant personnel.
- Opening lines and equipment.
- Changing seals and valves on on-line equipment.
- Changing seals and packing on pumps and valves.
- Changing and replacing pipes as required.
- Checking fluid levels in process equipment.
- Performing vibrational analysis.
- Performing steam tracing techniques.
- Testing and replacing pressure release valves as needed.
- Calibrating instruments and checking standards.
- Troubleshooting problems in processes and instrumentation as required.
- Inspecting and testing safety control equipment and devices.

P5 Modules

01 GENERAL CONCEPTS IN MAINTENANCE 327

02 MAINTAINING PROCESS EQUIPMENT 329

03 OPERATING AND MAINTAINING INSTRUMENTS 331

04 TROUBLESHOOTING TECHNIQUES 333

05 VIBRATION AS A MAINTENANCE TOOL ... 335

06 USE OF HUMAN SENSES IN PLANT CONTROL 337

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level PTs are expected to:

- Describe the types of maintenance and the importance of planned, preventive maintenance.
- Use a variety of on-line instruments common to the process industry, including but not limited to, those that measure gas and liquid concentrations, pH, and conductivity.
- Observe deteriorating conditions in process operations, using both human senses and instrument readings.
- Define terms used to characterize instruments and describe components and operations.
- Recommission instruments by providing routine maintenance and by troubleshooting problems.
- Determine when maintenance is required.
- Use a variety of on-line control equipment.
- Describe vibrational analysis techniques and their application to plant maintenance.
- Recognize abnormal operation of elements that sense temperature, pressure, flow, level, and other measurable properties.
- Describe feedback loops and the relationship between a controller and the sensing element.
- Recognize possible causes of failure of equipment and instruments.
- Identify at least six different kinds each of pumps and valves and be able to commission and decommission each one, including completing appropriate documentation.
- Recognize inefficient mixing and suggest corrective action.
- Demonstrate the ability to change and repack valves and other fittings.
- Set up a maintenance schedule according to good process management standards.

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P5.01

GENERAL CONCEPTS IN MAINTENANCE

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Give examples of different kinds of maintenance (scheduled, unscheduled, and preventive) and identify the role of the process technician (PT) in each.

02 Describe duties and tasks of a maintenance technician and the relationship of the PT to the maintenance technician.

03 Prepare a properly descriptive work request for maintenance.

04 Develop criteria for specific maintenance needs and recognize when these needs have been effectively addressed.

05 Describe consequences of not having a preventive maintenance program.

06 Visit a plant during turnaround; observe the activities of technicians; discuss the observations with plant personnel; and prepare for fellow students a report about the responsibilities of PTs during turnarounds.

07 Prepare a maintenance log for all instruments and equipment used in the PT training program.

Recommended Competencies

08 Develop and monitor a preventive maintenance schedule for school process equipment.

09 Estimate the added cost of malfunctioning equipment and poor maintenance to the total cost of product in a chemical plant.

P5.02

MAINTAINING PROCESS EQUIPMENT

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Demonstrate the ability to recognize major types of plant equipment, including piping valves, pumps, compressors, heat exchangers, tanks, distillation columns/towers, cooling towers, and reactors.

02 Using graphics and actual equipment parts, explain the purposes of common internal configurations for major pieces of plant equipment.

03 Compare the operations of a variety of valves (including globe, gate, diaphragm, ball, plug, check, and butterfly) and identify the service for which each type of valve is best suited.

04 Choose appropriate packing material and properly repack a variety of valves.

05 Describe isolation, blinding, and decontamination procedures for a variety of tanks and vessels.

06 Identify the effects on one or more process systems of the following:
  - fouled heat exchanger
  - damaged trays in a distillation tower
  - short or break in a thermocouple
  - plugged or restricted flow

07 List the conditions that determine when equipment needs to be removed from service.

08 Conduct inspections to evaluate equipment condition (e.g., inspection of internals of vessels during shutdowns).

09 Follow standard operating procedures (SOPs) to prepare equipment for maintenance.

10 Start up lubrication and seal oil systems; maintain proper oil levels during operation.

Continued

11 Describe symptoms of common pumping problems and cite appropriate corrective actions.

12 Demonstrate good practices for breaking flanges and installing and removing figure-eight and slip blinds, etc.

13 Describe causes of problems in fans, blowers, and compressors; cite appropriate corrective actions.

14 Apply lockout/tag-out procedures for removing motors from service and for preventing the release of potential, stored, or hazardous energy.

Recommended Competencies

15 Identify specific problems with a piece of equipment (e.g., gradual change in outlet temperature of a cooler), monitor to establish the trend, and determine when maintenance is required.

Maintenance is a proactive means to ensure that a plant operation runs smoothly and safely. Process technicians who follow preventive maintenance procedures are a valuable asset to the plant. For example, a chlorine compressor had a timer connected to it that sounded every 30,000 hours, indicating the compressor needed replacement gaskets and seals. If the compressor runs for much longer, the risk of leakage rapidly increases, potentially mixing chlorine and oil, which could severely damage the compressor and the process. Upon hearing the timer sound, the process technician acted quickly to start up the reserve compressor and take down the compressor that needed maintenance. Once the maintenance was complete and the compressor was running again, the technician entered critical data into the database. Equipment data such as the date of maintenance, the types of maintenance performed, the chlorine flow, and the oil level can be used at later dates for troubleshooting and preventive maintenance.

OPERATING AND MAINTAINING INSTRUMENTS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify instruments and other devices that are used in plants to monitor flow, level, pressure, temperature, and analytical targets and describe how they work; include analog, digital, and pneumatic instruments.

02 Have experience using on-line and laboratory instruments that measure pH, conductivity, composition, level, temperature, and pressure.

03 Relate changes in equipment performance to instrument measurements.

04 Identify the appropriate conditions for using cascade, split-range, and bias controllers.

05 Identify reasons for instrument failure such as clogged orifices and shorted thermocouples.

06 Determine when sensing elements are behaving abnormally and determine how to take corrective action.

07 Collect data from on-line instruments and recognize process trends.

08 Commission and decommission instruments by
- setting up instruments and adjusting settings
- tuning instruments
- reading and interpreting gauges and meters

09 Remove instruments from automatic service; convert the process variable to manual control.

Continued

P5.03

Recommended Competencies

10 Calibrate an on-line gas chromatograph.

11 Develop a list of service requirements for the instruments associated with the institution's process technician program.

12 Relate the control requirements of processes to the precision and accuracy of the instruments.

It is important for process technicians to be proficient in the operation and maintainence of instruments so that in the event of a malfunction they can maintain operations and ensure quality products are being produced. In a plant, a flow loop on control was reading 50%, which was, in fact, the correct reading for the loop. To obtain the 50% flow rate, the technician needed to keep the output to the control valve 35% open. At one point during the process, the sensor malfunctioned and indicated a 0% flow rate even though the actual flow was at the correct 50% rate. Because of this faulty reading, however, the computer system automatically opened the flow control valve to 100% open. The technician knew that if the 50% flow rate was not maintained, the product and process could be disrupted. The technician, who had prior experience in operating the equipment associated with this process, manually turned the valve to 35% from 100% to control the process and bring the operation back to normal.

P5.04

TROUBLESHOOTING TECHNIQUES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Use several fact-gathering processes, including interviews with personnel, data logs, and other information retrieval techniques.

02 Use process-of-elimination techniques to isolate problems.

03 Use several troubleshooting schemes (e.g., root cause analysis) to identify and diagnose problems.

04 Given a set of upset operating conditions, isolate variables with sufficient specificity to identify causes of problems and recommend ways to return the unit to normal operations.

Because process technicians are intimately involved with a plant process and the equipment for that process, they are responsible for a significant amount of troubleshooting. Technicians must take into consideration the instruments, equipment, and environment. For example, a plant technician was engaged in a routine start-up of a pump on a cold morning when the automated computer control system engaged automatic emergency shutdown due to loss of feed to the reactor. The technician investigated the reason for the system flow failure by conducting a systematic check of potential problems, including feed tank level, flow control, valves, flow transmitters, feed lines to the reactor, and pressure gauges. The technician narrowed the problem to frozen feed in the lines to the reactor. With the problem identified, the technician suggested a solution that would complete project goals with minimum downtime. Once the operation was running again, the technician suggested insulating feed pipes, which would prevent such events in the future.

P5.05

VIBRATION AS A MAINTENANCE TOOL

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the importance of vibration as a maintenance tool.

02 Use hand-held vibration meters.

03 Use axial and radial vibration measurements and associated techniques to determine equipment performance and identify maintenance needs.

04 Interpret data from vibration meters and analyzers.

05 Relate the vibration frequency and amplitude to safe, rough, danger, and shutdown levels.

Recommended Competencies

06 Use instruments to detect the location of distress (inboard bearings, outboard bearings) in rotating and reciprocating equipment.

Vibration is a good indicator for bearing wear. As bearings become increasingly worn, more vibrations occur, causing friction, heat, and additional wear. As part of routine preventive maintenance activities, technicians use hand-held devices to recognize vibrations that could damage equipment. A green light on the sensor indicates that the equipment is functioning properly. A yellow light indicates that vibration is minimal but that the bearings are beginning to wear and should be replaced soon. A red light indicates that bearings need to be replaced immediately. For example, using a hand-held vibration sensor, a technician checked a pump and noticed a yellow light. The technician notified the maintenance team that bearings needed to be replaced soon and asked to schedule some time for the maintenance. Then the technician started up the back-up pump and made sure it was running properly before shutting down the pump that needed repair. In doing this, the technician was able to keep the process running smoothly while maintaining the equipment.

P5.06

USE OF HUMAN SENSES IN PLANT CONTROL

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Apply human senses to detect small differences in sound, smell, vibration, temperature, etc., and describe how those differences may be used to analyze process behavior.

02 Distinguish, through human senses, the difference between normal and abnormal conditions; compare the sensed characteristics with field instruments and actual on-line instrument readings.

03 Correlate human fatigue with performance in process plants.

Recommended Competencies

04 Interview several process technicians at a local plant and assess how they make observations using their senses.

Human senses are often overlooked when considering the means by which a process technician works. Very often, senses are valuable to a technician when making periodic trips or "rounds" through the work area. Technicians use their senses constantly, whether they are reading an instrument, listening for vibrations, smelling for odors, or feeling for heat. For example, a technician smelled smoke during a routine walk through a plant. Carefully looking over the area, the technician noticed that a small generator seemed to be overheating, causing a small stream of smoke. By reacting to the faint smell, the technician was able to take the generator out of service, replace it, and allow the process to continue uninterrupted.

P5

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 340

COMPUTER 341

COMMUNICATION 342

MATH & STATISTICS

Providing Routine and Preventive Maintenance and Service to Processes, Equipment, and Instrumentation	MODULES					
	01	02	03	04	05	06
Read & Construct Graphs	✓	✓	✓	✓	✓	
Calculate Ratios	✓	✓	✓	✓	✓	
Perform Unit Conversions	✓	✓	✓	✓	✓	
Perform Calculations Using Exponents		✓	✓		✓	
Perform Calculations Using Roots		✓	✓		✓	
Perform Calculations Using Logarithms		✓	✓		✓	
Use Appropriate Significant Figures				✓	✓	
Recognize Patterns from Data	✓	✓	✓	✓	✓	✓
Solve Single-Unknown Algebra Equations	✓		✓	✓	✓	
Calculate Means & Standard Deviations			✓	✓	✓	
Calculate Accuracy & Precision of Data Sets			✓	✓	✓	
Determine Control Limits	✓	✓		✓	✓	
Determine Detection Limits		✓	✓	✓	✓	

COMPUTER

Providing Routine and Preventive Maintenance and Service to Processes, Equipment, and Instrumentation	MODULES					
	01	02	03	04	05	06
Use a Computer Keyboard	✓	✓	✓	✓	✓	
Access Database Information	✓	✓	✓			
Develop & Maintain a Database		✓	✓	✓	✓	
Use, Maintain & Develop Spreadsheets		✓	✓	✓	✓	
Use Graphics Software		✓	✓	✓	✓	
Use Microprocessors		✓				
Use Statistical Software				✓	✓	
Transfer Data to & from Remote Databases					✓	
Conduct On-line Literature Searches	✓			✓	✓	

COMMUNICATION

Providing Routine and Preventive Maintenance and Service to Processes, Equipment, and Instrumentation	MODULES					
	01	02	03	04	05	06
Oral Communication	✓	✓	✓	✓	✓	✓
Written Communication	✓	✓	✓	✓	✓	✓
Read & Understand Procedures		✓	✓	✓	✓	
Maintain Log & Notes	✓	✓	✓	✓	✓	✓
Keep Records	✓	✓	✓	✓	✓	✓
Write Memos & Letters	✓	✓	✓	✓	✓	✓
Write Technical Reports			✓			
Give Clear, Concise Instructions		✓	✓	✓	✓	
Report Data		✓	✓	✓	✓	
Maintain Accurate Notebook			✓	✓	✓	
Read & Prepare Diagrams		✓	✓	✓	✓	✓
Write Methods				✓		
Conduct Literature Searches		✓	✓	✓	✓	
Read Technical Manuals & Journals			✓	✓	✓	

ANALYZING PLANT MATERIALS

Introduction

As the nature of work changes, process technicians (PTs) are expected to participate in an increasing number of aspects of plant operations. Technicians, as members of teams, will require the skills to perform work traditionally done by specialists. One such area is making chemical and physical measurements, where technicians conduct standard procedures to measure product and process quality. To develop this skill, the technician will need to have basic training for laboratory operations in areas such as sampling; concepts of measurements; following procedures; and performing physical, chemical, and instrumental tests. The interface between a centralized laboratory and a unit laboratory will vary from company to company and location to location, and the jurisdictions of each will need to be determined at the local level.

The modules developed for this Critical Job Function provide the PT with sufficient skill to provide support in the plant laboratory.

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TASKS

Tasks conducted by PTs related to this Critical Job Function include:

- Following specified procedures to collect appropriate samples for analysis from process streams or products (solids/liquids/gases).
- Visually inspecting samples to ensure adequate representation of the sampled materials and determining whether any immediate response is required.
- Labeling samples appropriately and according to any prescribed procedures.
- Delivering samples in a condition representative of the material to testing locations.
- Preparing necessary reagents and standards required to conduct tests.
- Calibrating instruments as required.
- Analyzing quality control standards to appropriate precision levels by using prescribed methods.
- Performing appropriate physical and chemical tests, according to standard procedures.
- Calculating results using calculators and computers.
- Determining whether resampling and reanalyzing are necessary.
- Maintaining an analysis area to ensure correct results will be produced repeatedly.
- Reporting results using prescribed procedures or effective presentation techniques to appropriate personnel.
- Adjusting process parameters as necessary following standard practice or as appropriate to respond to analytical results.
- Entering data into computers and other appropriate logs.
- Reviewing trends of process variations and sampling analyses.
- Comparing sample analyses with control values and responding appropriately.
- Preparing proper paperwork to submit samples to the laboratory.

TECHNICAL WORKPLACE STANDARDS

For this Critical Job Function, entry-level PTs are expected to:

- Characterize gases, liquids, and solids.
- Describe procedures for obtaining representative samples of solids and liquids and demonstrate use of appropriate techniques.
- Describe sampling devices for use with gases under pressure and demonstrate how to use typical sampling devices.
- Sample a flowing liquid stream.
- Describe proper techniques for handling materials, including industrial hygiene, safety, and environmental considerations.
- Choose proper containers for a variety of solids, liquids, and gases, each with a wide range of physical properties.
- Write common and standard chemical names and use symbols appropriate for the local industries.
- Demonstrate standard labeling procedures.
- Measure pH using a variety of common techniques and demonstrate proper care and maintenance for each technique.
- Identify proper procedures and implement standard measurement and analytical procedures, such as American Society for Testing and Materials (ASTM) and Association of Official Analytical Chemists (AOAC) standards.
- Calculate normality, molality, and molarity; prepare standard solutions.
- Describe at least 20 physical properties of materials, including specific gravity, density, flash point, and viscosity; describe measurement methods for each.
- Select appropriate devices or techniques and measure at least 15 different physical properties.
- Conduct chemical analyses using volumetric techniques, such as acid–base titrations and redox titrations.

Continued

P6
Modules

01 **BASIC CONCEPTS OF MEASUREMENT 347**

02 **CHEMICAL AND PHYSICAL PROPERTIES OF SOLIDS, GASES, AND LIQUIDS ... 349**

03 **ANALYTICAL METHODS .. 351**

04 **OBTAINING SAMPLES FOR MEASUREMENT 353**

05 **CARRYING OUT STANDARD PROCEDURES 355**

06 **MEASURING pH 357**

07 **VOLUMETRIC ANALYSIS USING TITRATIONS 359**

08 **ANALYTICAL INSTRUMENTATION 361**

09 **STATISTICS FOR THE LABORATORY 363**

10 **HANDLING LABORATORY EQUIPMENT SAFELY 365**

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- Use instrumental methods such as gas chromatography (GC), infrared (IR) spectroscopy, basic spectrophotometry, and colorimetry and describe the theory applicable to each.

- Describe pressure and temperature relationships for all states of matter.

- Balance simple chemical equations.

- Perform calculations involving stoichiometry, solutions, and physical properties.

- Set up, use, and maintain automated equipment for conducting tests.

BASIC CONCEPTS OF MEASUREMENT

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe the importance of measurement in chemistry.

02 Define "precision" and "accuracy"; give examples of each.

03 Calculate mean, median, mode, and standard deviation for several data sets.

04 Develop a frequency distribution chart for a data set.

05 Describe a control chart and construct such a chart using a data set.

06 Define what is meant by an "out-of-control" measurement.

07 Define "confidence limit" in terms of standard deviation.

08 Describe what is meant by "significant figures"; give examples.

09 Compare systematic and random errors.

10 Select and use analytical balances for weighing quantities ranging from 0.001 grams to 100 grams to a specified accuracy and precision.

11 Identify, select, and demonstrate proper use of volumetric glassware (burets, graduated cylinders, flasks, and pipets).

12 Calibrate volumetric glassware.

13 Calculate the errors in various measurements based on data acquired using common laboratory equipment.

Continued

14 Apply standard rules for determining the number of significant figures in measurements and in the answers to corresponding calculations.

15 Convert units of measure from English to metric and vice versa.

Recommended Competencies

16 Evaluate propagation of error in a calculation involving one or more steps.

17 Calibrate storage containers, safety testing equipment, and air and water monitoring equipment.

Accurately measuring physical properties is a routine but important function of all process technicians. Technicians who use the correct instruments and implement the correct procedures are more likely to yield accurate results. For example, a technician was measuring the specific gravity of a shipment of hydrofluorosilic acid using a standard laboratory procedure. Unfortunately, the technician's result did not agree with the manufacturer's claim of product strength. The technician conducted research to identify the appropriate method for measuring specific gravity and concluded that the existing laboratory procedure was not applicable. The technician identified the correct procedure, remeasured the manufacturer's shipment using the correct procedure, and concluded that the acid was, in fact, as strong as the manufacturer had claimed.

P6.02

CHEMICAL AND PHYSICAL PROPERTIES OF SOLIDS, GASES, AND LIQUIDS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Characterize gases, liquids, and solids according to their physical states.

02 Calculate pressure, temperature, and volume relationships for gases and liquids.

03 Use the ideal gas law to calculate pressure, temperature, and volume relationships for gases.

04 Characterize common chemical materials based on the following physical and chemical properties; identify the units applicable to each; identify the apparatus used to measure each; and cite the importance of the property to characterize the product:

- boiling point
- dew point
- density/specific gravity
- freezing point
- cloud point
- flash point
- hardness
- pH
- viscosity
- heat of combustion
- color
- pour point
- fire point
- specific heat
- solubility
- vapor pressure/temperature

Continued

05 Conduct several physical measurements of interest to local industry, including setting up the apparatus, performing the calibration, running test materials, calculating results, and returning the apparatus to working condition for the next test.

06 For the above measurements, describe how standard units were set up for English and metric systems; then convert the values obtained in the measurements from English to metric units using a handbook or other reliable source of conversion factors.

When chemical manufacturers ship chemicals, they do so in a variety of containers ranging from tank cars to steel drums. It is important for a process technician to use knowledge of chemical materials to confirm that the material is as it is labeled. For example, a technician took a sample of material from a recently received container for analysis. The technician determined the specific gravity of the sample and compared it with the known specific gravity of the material. Because the specific gravity matched perfectly, the technician was confident that the chemical was exactly as it was labeled.

ANALYTICAL METHODS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify the associations that develop and evaluate analytical methods for chemical analysis (e.g., American Society for Testing and Materials [ASTM], Association of Official Analytical Chemists [AOAC], U.S. Pharmacopeia [USP]).

02 Use manual and on-line techniques to identify appropriate reference materials and locate analytical methods for specific analytical requirements.

03 Identify the specific sections of a standard method, including scope, equipment, safety considerations, calibration, method, precision, accuracy, repeatability, and reproducibility.

04 Apply a company reference method and determine the accuracy and precision expected.

Recommended Competencies

05 Write an analytical method to conduct a chemical analysis.

Mechanical integrity of a plant may depend on performing some infrequently used methods. When using these methods, process technicians need to be particularly careful. For example, a production plant had been shut down for repairs and maintenance. The technician knew that moisture, which collected on the equipment during downtime, could cause corrosion, leaks, and gas release. To assess the extent of the condensation, the technician needed to conduct moisture analysis. This analysis was necessary only when the plant was out of service—which wasn't very often—and, consequently, the technician wasn't familiar with the exact procedures. Using the on-line computer database, the technician printed the procedure for moisture analysis and followed the procedure carefully so that the analysis was accurate. It was only after the analysis was performed to the satisfaction of the technician that the plant was allowed to go back into service.

P6.04

OBTAINING SAMPLES FOR MEASUREMENT

Upon completion of this module, the technician will be expected to:

Core Competencies

01 State reasons why collecting representative samples is required.

02 Identify a variety of sampling devices used in either continuous or batch processes and identify the specific use of each one.

03 Locate continuous and periodic sampling points on process diagrams.

04 Recognize and use a variety of sample containers appropriate for a variety of samples.

05 Safely obtain representative samples from bulk solid and liquid materials.

06 Safely obtain representative samples from process streams, taking into account concepts of process lag time, proper mixing, and contamination prevention.

07 Handle volatile materials safely.

08 Safely obtain samples that are stored under pressure.

09 Use sampling techniques appropriate to protect the environment.

10 Label samples according to safety/health and environmental (S/H/E) guidelines.

11 State reasons why samples must be homogeneous for analysis and use equipment to ensure homogeneity.

Recommended Competencies

12 Apply various techniques to the preparation of solid, liquid, and gas samples for analysis: Grind solid materials using a mortar and pestle, a ball mill, and a mill grinder; dissolve liquid samples in aqueous and nonaqueous solvents; digest samples if necessary to get them into a measurable form.

Continued

P6.04

Obtaining representative samples of a chemical material can be one of the most challenging tasks for a technician. If sampling is not performed correctly, high-quality products could be mistaken for poor-quality products, leading to significant waste in company resources. For example, symmetrical tetrachloropyridine, a component of an insecticide, must have a purity of at least 99%. A process technician, taking samples from a storage vessel, was surprised to find purity much less than 99%. After taking multiple samples that supported low-purity results, the technician concluded that either the batch was poorly manufactured or that something was wrong with the sampling process. The technician decided to conduct some research before beginning the costly process of disposing of the product. Notebooks and records revealed that the previous batch of product was indeed manufactured poorly. Additionally, the technician discovered that the storage vessel had not been flushed between batches. The technician thought that perhaps a stagnant location of the vessel was harboring remnants from the previous batch and contaminating the new batch. The technician decided to flush the vessel completely, refill the vessel with the product, and resample. The technician's careful thought and follow-up paid off; the flushing did clean the vessel, and the subsequent samples proved that the batch was well above the 99% purity threshold.

P6.05

CARRYING OUT STANDARD PROCEDURES

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Perform each step in common analytical laboratory procedures.

02 Identify the sources of standard methods and apply, in measurements, the terminology commonly used in each of the methods, including those that are company specific (U.S. Pharmacopeia [USP], American Society for Testing and Materials [ASTM], Association of Official Analytical Chemists [AOAC], Environmental Protection Agency [EPA], etc.).

03 Given a variety of analytical procedures published by different organizations, identify key information required to perform the procedure correctly and safely.

04 For a variety of analyses, identify the appropriate standard method; demonstrate the ability to perform the procedure and evaluate the method or procedures in terms of accuracy, precision, repeatability, and reproducibility.

05 Write a report describing the work done, the results, and the information regarding the accuracy of the measurement.

Recommended Competencies

06 Conduct several analytical procedures of interest to the local industry, including obtaining a sample, setting up the required apparatus, performing the calibration and running test materials, performing tests, calculating results, and returning apparatus to working condition for the next test.

Oftentimes, standard procedures become so routine that process technicians can perform them without using manuals, notes, or checklists. If the technician is not careful, this practice can result in a series of mistakes, inaccurate results, and consequences due to noncompliance with regulations. For example, at a styrene plant, gas chromatographs were used to test properties of the product. The gas chromatograph required a solution composed of a given sample and a carrier material at a 1:10 dilution. A process technician, having "memorized" the routine standard procedures, confused this process with another. Instead of composing a 1:10 dilution, the technician composed a 1:5 dilution. Consequently, the gas chromatograph readings were completely off-spec. In reviewing the standard procedures as stated in the company manuals, the technician saw the mistake and performed the analysis correctly.

P6.06

MEASURING pH

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Describe pH as it relates to acid and base strength of materials.

02 Characterize, using a pH meter or other indicator, several materials as to acid or base strength.

03 Make pH measurements at a process unit as well as in the laboratory and compare the data.

04 Calibrate a pH meter using buffer solutions.

05 Demonstrate proper care and maintenance for a pH meter electrode.

Measuring pH is one of the most fundamental tasks performed by a process technician. The pH level of the water in cooling towers, for example, must be maintained within a certain range. If the pH is too high, then scaling could occur. If the pH is too low, then corrosion could occur. To monitor the pH, the technician can use one of two techniques. A technician used a method of pH measurement employing an on-line pH meter at the cooling tower. The technician compared the reading with a manual reading taken from a sample of the water. As long as the readings matched, the technician knew that the pH level was acceptable. When the readings differed, however, the technician needed to check the meter in the lab with a known buffer. By doing this, the technician was reassured that the meter was working correctly and took the necessary steps to adjust the flow of the chemicals used to treat the cooling tower.

P6.07

VOLUMETRIC ANALYSIS USING TITRATIONS

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Identify and appropriately use and care for the glassware used in volumetric analyses, including pipets and burets.

02 Define "normality," "molarity," and "molality" and describe the experimental conditions when each is appropriate.

03 Relate formula weight to number of moles and equivalent weight to number of equivalents.

04 Demonstrate the relationship between volume and normality.

05 Calculate the amount of material required to prepare solutions of specified normality given the equivalent weight and/or the reaction for which the solution will be used (acid–base and redox titrations).

06 Standardize solutions of known concentrations (normal, molar, and molal) using appropriate primary standards.

07 Follow a lab method to perform various titrations (acid–base, complexometric, precipitation, redox, etc.).

Recommended Competencies

08 Perform various titrations using autotitrators.

09 Prepare solutions of required normality, molarity, and molality for a variety of measurements.

Even when certain skills are not a normal part of day-to-day activities, a process technician must be capable of performing them. For example, at a chloralkali plant, automatic analysis for NaOH is conducted by performing titrations using a standard solution of HCl. A disruption in the NaOH schedule analysis could trigger downstream process problems, and therefore it is important to monitor the process regularly. During a graveyard shift, a technician discovered that the HCl reservoir was empty, and there was no backup supply of standard HCl solution. Thinking quickly, the technician found some stock HCl that was of higher concentration than the standard solution. With the knowledge of volumetric analysis, the technician diluted the HCl, checked titration results from a sample of a known concentration, and was able to keep the process going overnight without interruption.

P6.08

ANALYTICAL INSTRUMENTATION

Upon completion of this module, the technician will be expected to:

Core Competencies

01 For the analytical instruments listed below, describe the principle of, operation, and use in a plant laboratory:
- gas chromatograph
- high-performance liquid chromotagraph
- total organic carbon (TOC) analyzer

02 Describe the application of the following instruments in a plant laboratory:
- infrared (IR) spectrometers
- ultraviolet–visible (UV–vis) spectrometers
- atomic absorption (AA) spectrometers

Recommended Competencies

03 Perform analysis using:
- gas chromatograph
- high-performance liquid chromatograph
- TOC analyzer
- IR spectrometer
- UV–vis spectrometer
- AA spectrometer

Most continuous process units are equipped with analytical instruments to measure properties of feed, intermediate, and/or product streams. This is particularly important to locations that receive and transmit materials by pipeline, without intermediate storage. The time lag involved in product sampling for analysis by a central laboratory can be prohibitive because by the time the results are available the material is in the customer's pipeline. For example, at a chemical unit that monitored an important product, a continuous analyzer failed. Without the analyzer, the technician did not have critical information about contaminants in the product. The process technician noted that a nearby analyzer in a less critical service could be adapted with relatively little change. By rerouting the sample line and checking the analyzer calibration, the revision was accomplished in several hours and averted the possibility of releasing off-spec product.

P6.09

STATISTICS FOR THE LABORATORY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Define "precision," "accuracy," "reproducibility," and "repeatability" as these measures apply to the control of processes; give appropriate examples of each.

02 Present data graphically using linear and log scales.

03 Calculate mean and standard deviation for a variety of data sets from chemical processes; apply these statistical measures to the analysis of the data sets.

04 Given a data set, construct control charts identifying the upper and lower control limits.

05 Define "confidence limits."

Recommended Competencies

06 Construct a control chart using data obtained by a variety of class members.

Statistics are used by process technicians for a variety of purposes, most common of which is process control. Technicians are typically responsible for gathering data; plotting data; calculating averages, means, and standard deviations; and making preliminary interpretations of the results. For example, a technician constructed a control chart for the melt flow rate of polypropylene plastic produced from a process. The technician then calculated and plotted the upper and lower control limits. The technician took special care in performing these calculations. Even small mathematical errors could mislead the technician. The technician plotted the subsequent data and was assured that, because all points were falling within the ranges, the process was stable and in statistical control.

P6.10

HANDLING LABORATORY EQUIPMENT SAFELY

Upon completion of this module, the technician will be expected to:

Core Competencies

01 Demonstrate safe handling procedures for a variety of types of laboratory equipment.

02 Use, store, and transport compressed gas cylinders correctly and safely.

03 Choose proper regulators for gases and other materials under pressure and under vacuum.

04 Assess safe handling procedures for a variety of volatile chemicals.

05 Maintain glassware safely, including making connections, cleaning, and storing.

06 Explain how the maintenance program of equipment and laboratory facilities contributes to safe and efficient laboratory operations.

07 Apply the basic laws of electricity; identify common components of electrical and electronic circuits and demonstrate how to create a safe working environment involving laboratory electrical devices.

For safety and functional reasons, process technicians need to understand how to handle laboratory equipment appropriately. For example, many facilities use cylinders of high-pressure helium common in industry. A full cylinder is typically at 2000 psi and must be handled with extreme care. A technician was replacing an empty cylinder with a full cylinder and took special precautions to ensure that the replacement was done safely. Before disconnecting the empty cylinder, the technician had to make sure that it was secured to the wall. When disconnecting the cylinder, the technician used care so that the valves, tubing, and piping would not get crimped or otherwise damaged; any damage to these components could have been hazardous when the cylinder was refilled. The technician also installed a safety cap on the cylinder. Before connecting the full cylinder, the technician secured it to the wall to prevent it from tipping over. With some simple precautions, the technician was able to perform the equipment change without incident.

EMPLOYABILITY WORKPLACE STANDARDS

MATH & STATISTICS 368
COMPUTER 369
COMMUNICATION 370

P6

MATH & STATISTICS

Analyzing Plant Materials	MODULES									
	01	02	03	04	05	06	07	08	09	10
Read & Construct Graphs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Calculate Ratios	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perform Unit Conversions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Perform Calculations Using Exponents	✓					✓				
Perform Calculations Using Roots						✓				
Perform Calculations Using Logarithms		✓				✓				
Use Appropriate Significant Figures	✓	✓	✓	✓	✓	✓	✓	✓		✓
Recognize Patterns from Data		✓	✓	✓	✓	✓	✓	✓		✓
Solve Single-Unknown Algebra Equations		✓		✓	✓	✓	✓		✓	✓
Calculate Means & Standard Deviations	✓	✓	✓	✓	✓	✓	✓	✓		✓
Calculate Accuracy & Precision of Data Sets	✓				✓	✓	✓		✓	✓
Determine Control Limits	✓				✓	✓	✓	✓	✓	✓
Determine Detection Limits	✓				✓	✓	✓	✓	✓	✓

COMPUTER

Analyzing Plant Materials	MODULES									
	01	02	03	04	05	06	07	08	09	10
Use a Computer Keyboard	✓		✓		✓	✓		✓	✓	✓
Access Database Information	✓		✓		✓	✓	✓	✓	✓	✓
Develop & Maintain a Database				✓	✓	✓	✓	✓	✓	✓
Use, Maintain & Develop Spreadsheets			✓		✓	✓	✓	✓	✓	✓
Use Graphics Software								✓	✓	
Use Microprocessors				✓	✓	✓	✓	✓	✓	
Use Statistical Software				✓	✓	✓		✓	✓	
Transfer Data to & from Remote Databases				✓	✓	✓	✓	✓	✓	
Conduct On-line Literature Searches	✓		✓		✓				✓	

COMMUNICATION

Analyzing Plant Materials	MODULES									
	01	02	03	04	05	06	07	08	09	10
Oral Communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Written Communication	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Read & Understand Procedures	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintain Log & Notes		✓	✓	✓	✓	✓	✓	✓	✓	✓
Keep Records				✓	✓	✓	✓			✓
Write Technical Reports				✓		✓				
Give Clear, Concise Instructions		✓		✓	✓	✓	✓	✓	✓	✓
Report Data		✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintain Accurate Notebook			✓	✓	✓	✓	✓	✓	✓	✓
Read & Prepare Diagrams			✓	✓	✓	✓	✓	✓	✓	✓
Write Methods			✓		✓					
Conduct Literature Searches	✓					✓				
Read Technical Manuals & Journals	✓		✓					✓		

SECTION III:

IMPLEMENTATION OF THE VOLUNTARY INDUSTRY STANDARDS

INTRODUCTION

ALLIANCES

TRAINING MATERIALS RESOURCE DATABASE

TOOLS FOR IMPLEMENTING SKILL STANDARDS
- Curriculum Analysis Matrix
- Gap Analysis Matrix

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INTRODUCTION

The skill standards as presented in this report represent "building blocks" that are intended to be used by educational institutions and in the workplace to develop the technical workforce required by the U.S. chemical process industries (CPI). To be effective, the skill standards must be implemented locally within frameworks established by individual states. Two major issues need to be addressed for the skill standards to be implemented at the local level. The first is the creation of alliances involving government, industry, education, labor, and the community to share the responsibility to develop and upgrade the workforce; the second is to develop model instructional materials to support the learning. Tools have been modeled that assess the skill standards required by industry and what is being taught by educators.

As a component of the Voluntary Industry Standards for Chemical Process Industries (CPI) Technical Workers, a study was conducted by the Triangle Coalition for Science and Technology Education to provide insight into alliance formation as a way to facilitate the implementation of skill standards at the local level. The study involved facilitating meetings at three locations: Houston, Syracuse, and Pittsburgh. At each location, representatives from industry, education, and the community participated in facilitated focus group sessions and identified the benefits derived from participating in local alliances as well as barriers to effective alliances. From the results of the study (a complete report of the study is available from the American Chemical Society) and from data collected while developing the skill standards, the following definition was derived:

> *An alliance represents a shared responsibility which benefits Industry, Education, Labor, Community, and Government in the development of the human resources required for High Performance Workplaces in the Chemical Processing Industry using Skill Standards as a foundation. To accomplish this, Alliances would:*
>
> - *continuously update and improve skill standards*
> - *develop curricula based on student needs*
> - *provide workplace experience for students*
> - *provide developmental activities for faculty*
> - *share financial, capital, and human resources*
> - *monitor employment trends*
> - *develop and maintain a skill development path throughout the educational experiences*
> - *provide career guidance information*
> - *provide for public relations*
> - *provide for sustainability*

With support from the National Skill Standards Board and the National Science Foundation, work is currently underway at six locations in the United States to develop models for alliance formation. The six locations (Gulf Coast region, Texas; Baltimore area, Maryland; New Jersey area; Mobile area, Alabama; Pittsburgh area, Pennsylvania; and the state of Illinois) were chosen because of the outstanding activities currently conducted and the high concentration of CPI companies in those areas. The results of this work will be made available in separate publications.

TRAINING MATERIALS RESOURCE DATABASE

The skill standards are presented in this report according to Critical Job Functions carried out by chemical laboratory technicians and process technicians. Skill development modules were developed as a way of sorting the information into discrete technical units. Competencies represent the outcomes of a technician having obtained proficiency. To effectively implement the skill standards, the skill development modules, containing the competencies, must by further expanded into instructional modules. The National Science Foundation is supporting an effort to develop model instructional materials that can be used by educators and industry in implementing the standards.

It is, however, clear that training and educational materials, which have been produced by vendors, schools, and industries, would be useful if they were accessible. Moreover, a sortable index of training materials would be useful for implementing skill standards.

As part of the Voluntary Industry Standards Project, Training & Development Systems, Inc., was contracted to develop an index of commercial and noncommercial training materials and a user-friendly software platform to enable the index to be sorted using the skill standards. The training materials resource database is included as a part of this publication. Three diskettes are provided with this report and can be used on a personal computer using Windows 95 or Windows 3.1 operating systems.

The training materials resource database provides two categories of data: materials and suppliers.

Materials data includes:

- title of the material
- material catalog number (if applicable)
- material description
- course type (instructor-led or self-paced)
- course format (computer, video, or text)
- course level (introductory, intermediate, or advanced)
- course length

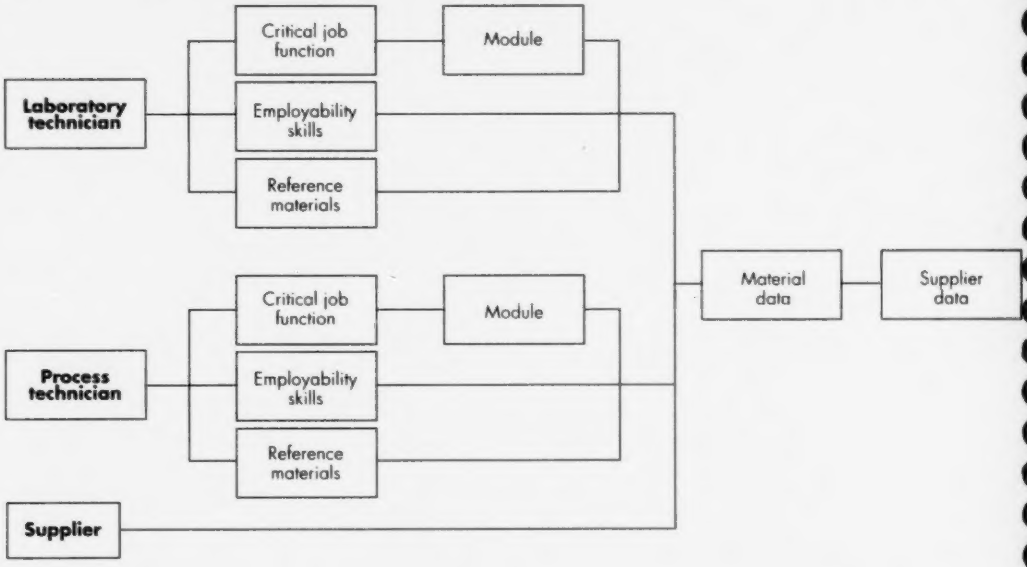
Supplier data includes:

- supplier name
- supplier address
- supplier phone number
- contact name
- supplier description

These data can be accessed via three sorting routes: "Chemical Laboratory Technician," "Process Technician," and "Supplier." For either the Chemical Laboratory Technician or Process Technician route, materials and supplier data can be sorted by Critical Job Function, skill development modules, employability skills (math and statistics, computer, or communication), or reference. In addition, materials can be accessed by the Supplier route. Figure 1 illustrates the flow of the database.

In total, the training materials resource database represents more than 1200 training materials from more than 30 commercial and noncommercial suppliers. Note that all of these materials were contributed voluntarily, and none of them were reviewed for content or quality.

Figure 1. Training materials resource database flow diagram.


Critical job function
Module
Laboratory technician
Employability skills
Reference materials
Material data
Supplier data
Critical job function
Module
Process technician
Employability skills
Reference materials
Supplier

Several tools have been developed and are being tested to compare college program offerings and employer needs. These include a curriculum analysis matrix and a gap analysis matrix. The curriculum analysis matrix is designed to assist colleges in determining the extent to which the skill development modules from the voluntary industry standards for chemical laboratory technicians (CLTs) and process technicians (PTs) are addressed in the curriculum; the gap analysis matrix is designed to help colleges assess the degree to which the current curriculum meets the competency needs as identified by the employers they serve.

The tools described below were developed collaboratively by the American Chemical Society Chemical Technology Program Approval Service and members of the Voluntary Industry Standards Project staff, facilitated by the Educational Development Center, Inc.

Curriculum Analysis Matrix

The curriculum analysis matrix assists colleges in assessing programs with regard to their ability to present the skills identified in the skill standards. The focus of the matrix is at the skill development module level. Using the matrix allows the college staff to answer the questions:

- Are the module topics covered in the existing course sequence? If so, where and in what order?
- In the courses currently offered, is the focus on theory, practice, or a combination of both?

This matrix can be used to identify the distribution of module topics across the program and to determine which additional topics should be included in future course offerings or course revisions.

Using the form shown below (one for each semester or quarter):

- At the top of each column identify the courses offered to students.
- List the skill development modules in the numbered rows.
- Review the competencies listed in each skill development module.
- Compare the competencies to the material offered in the course by using the key provided.
- Develop a list of topics to be eliminated from or included in future courses.

Module	Course	Course	Course
1			
2			
3			

Key:
O = Module material is NOT covered in the course
T = THEORY related to the Module covered in the course
P = Skills PRACTICED in the course

Gap Analysis Matrix

The gap analysis matrix is intended to be used collaboratively by schools and industry. The tool consists of three parts: the industry importance matrix is completed by industry; the educational institution capability matrix is completed by a program director or a team of faculty responsible for the college program; and the compilation form is completed by the program director to determine the extent to which existing curricula reflect the needs of industry.

Using the following codes, industry should rate each of the competencies listed in the skill standards according to importance:

0 = Not important for technicians
1 = Technicians should be aware of the knowledge/skill but are not required to use it
2 = Technicians are expected to understand, use, and practice this knowledge/skill with supervision
3 = Technicians are expected to demonstrate mastery of this knowledge/skill, solve problems, integrate this with other knowledge/skill sets, apply this knowledge/skill to new situations, and teach it to others

Using the following codes, educational institutions should rate the competencies in the skill standards according to their inclusion in a curriculum:

0 = Not covered in curriculum
1 = Curriculum introduces through vocabulary, readings, and facts
2 = Curriculum provides opportunities to understand, use, and practice this knowledge/skill with the help of the instructor
3 = Curriculum provides opportunities to master the knowledge/skill, solve problems, integrate, act independently, apply this knowledge/skill to new situations, and teach it to others

A compilation form should be completed by colleges to determine the gap between what is included in curricula and the current needs of local employers. The gap is given a numerical value by determining the difference between the employer score and the college score for each skill competency.

Individual Competencies	Importance to the Industry	Institutional Capability	Gap	Notes

The scores can be interpreted as follows:

- A difference in score between employers and colleges = 0

Interpretation: Our college is meeting employers' needs for this knowledge/skill set. Adjustments to the curriculum are not needed.

- A difference in score between employers and colleges = 1

Interpretation: Our college and local employers have somewhat similar views on this performance objective. Curriculum adjustments may not be needed.

- A difference in score between employers and colleges = 2

Interpretation: Our college and local employers have significantly different views on this performance objective. Curriculum adjustments might be needed.

- A difference in score between employers and colleges = 3

Interpretation: Our college is not meeting employer needs related to this performance objective. Consideration needs to be given to the performance objective and whether it should be added to or removed from the curriculum. Dialogue needs to be initiated with employer partners to discuss this knowledge/skill set.

APPENDICES

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COORDINATING COMMITTEE

CONTRACT CONTRIBUTORS

EMPLOYER CONTRIBUTORS

ACADEMIC INSTITUTION CONTRIBUTORS

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APPENDIX D

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North Carolina Biotechnology Center
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Occidental Chemical Corporation
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Phillips Petroleum Company
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Polychrome Corporation

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RWD Technologies, Inc.
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Solvay Polymers, Inc.
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Sun Refining and Marketing Company
Synthetic Organic Chemical Manufacturers Association
Technical Association for the Pulp and Paper Industry
Technology Training Systems, Inc.
Texaco Refining and Marketing, Inc.
Texaco Research and Development
Thiokol Corporation
Tosco Corporation
Union Carbide Corporation
United States Department of Agriculture
University of California, Berkeley
USDOC/OSHA Salt Lake Technical Center
Western Research Company, Inc.
Western Training Trust
Westinghouse Electric Corporation, SRC Analytical Labs
Westvaco Corporation
Williams Learning Network
WMX Technologies, Inc.
WTC Resins Pilot Plant
Zeneca Pharmaceuticals

APPENDIX E

ACADEMIC INSTITUTION CONTRIBUTORS

Alvin Community College
Bishop State Community College
Brazosport College
California University of Pennsylvania
Cape Fear Community College
Cincinnati State University
College of the Mainland
Community College of Philadelphia
Community College of Rhode Island
Community-Technical Colleges of Connecticut
Cornell University
Delaware Technical and Community College
East Vocational High School (Tennessee)
Eastern Idaho Technical College
Golden West College
ITT Educational Services
Lamar University
Lee College
Los Angeles Harbor College
Lower Columbia College
Miami University, Middletown (Ohio)
Michigan Technological University
Middlesex County College
Northeast State Technical College
Northhampton Community College
Onondaga Community College
Prince George's County Community College
Rio Honda College
River Parish Technical Institute
San Jacinto Community College
Seattle Community College (Central)
Southeast Community College
St. Louis Community College District
Stanford University
State Technical Institute at Memphis
Texas State Technical College
University of Cincinnati, College of Applied Science
University of Southern Mississippi

MEETINGS AND SESSIONS FOR THE DEVELOPMENT OF SKILL STANDARDS

Analysis Sessions

Baton Rouge, Louisiana, *(November 1993)*
Cincinnati, Ohio *(December 1993)*
Berkeley, California *(February 1994)*
Newark, New Jersey *(March 1994)*
Chicago, Illinois *(April 1994)*
Research Triangle Park, North Carolina *(April 1994)*

Working Meetings

Houston, Texas *(November 1993)*
Seattle, Washington *(February 1994)*
Philadelphia, Pennsylvania *(March 1994)*

Other Meetings

API Regional Meeting, Pittsburgh, Pennsylvania *(February 1994)*
TTS Refinery Manager User Group Meeting, Denver, Colorado *(March 1994)*
API National Meeting, Dallas, Texas *(May 1994)*
CMA Education Committee Meeting, Washington, DC *(June 1994)*
API National Meeting, Los Angeles, California *(October 1994)*
API Regional Meeting, Philadelphia, Pennsylvania *(November 1994)*
ACS National Meeting, New Orleans, Louisiana *(March 1996)*
API National Training & Development Conference, New Orleans, Louisiana (*November 1996*)

Skill Development Sessions: Chemical Laboratory Technicians

Performing Chemical Analysis, Philadelphia, Pennsylvania *(March 1995)*
Planning, Designing, and Conducting Experiments, Philadelphia, Pennsylvania *(March 1995)*
Performing Instrumental Analysis, Cincinnati, Ohio *(April 1995)*
Synthesizing Compounds, Cincinnati, Ohio *(April 1995)*
Sampling and Handling Chemical Materials, Cincinnati, Ohio *(April 1995)*
Maintaining a Safe and Clean Laboratory Adhering to Safety/Health and Environmental Regulations, Middlesex, New Jersey *(May 1995)*
Measuring Physical Properties, Middlesex, New Jersey *(May 1995)*
Laboratory Technician Review Meeting, Cincinnati, Ohio *(November 1995)*
Laboratory Technician Review Meeting, Indianapolis, Indiana *(May 1996)*

Skill Development Sessions: Process Technicians

Operating, Monitoring, and Controlling Batch Processes, Houston, Texas *(February 1995)*
Routine and Preventative Maintenance and Service to Processes, Equipment, and Instrumentation, Houston, Texas *(February 1995)*
Handling, Storing, and Transporting Chemical Materials, Middlesex, New Jersey *(May 1995)*
Operating, Monitoring, and Controlling Continuous Processes, Middlesex, New Jersey *(May 1995)*
Maintaining Safety/Health and Environmental Standards in the Plant, Long Beach, California *(June 1995)*
Analyzing Plant Materials, Long Beach, California *(June 1995)*
Process Technician Review Meeting, Houston, Texas *(January 1996)*
Process Technician Review Meeting, Houston, Texas *(June 1996)*

APPENDIX G

STANDARD INDUSTRIAL CLASSIFICATION CODES FOR THE CHEMICAL PROCESS INDUSTRIES

Industry Group

281	Industrial Inorganic Chemicals
282	Plastics Materials and Synthetic Resins, Synthethic Rubber
283	Drugs
284	Soaps, Detergents, Perfumes, Cosmetics
285	Paints & Enamels
286	Industrial Organic Chemicals
287	Agricultural Chemicals
289	Miscellaneous Chemical Products
291	Petroleum Refining
295	Asphalt Paving and Roofing
299	Miscellaneous Petroleum and Coal Products
301	Tires and Inner Tubes
302	Rubber and Plastics Footwear
305	Gaskets, Packing and Sealing Devices and Rubber and Plastics Hose and Belting
306	Other Fabricated Rubber Products
308	Miscellaneous Plastics Products
8731	Commercial Physical and Biological Research
8733	Noncommercial Research Organizations
8734	Testing Laboratories

For further information, contact:
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